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September 15, 2003

Food and Drug Administration
Office of Nutritional Products, Labeling and Dietary Supplements (HFS-800)
5100 Paint Branch Pkwy.
College Park, MD 20740

Subject: Petition for Health Claim (SSA) – Barley β-glucan Soluble Fiber and Barley Foods Containing β-glucan Soluble Fiber and Coronary Heart Disease

The National Barley Foods Council (NBFC) is hereby submitting a petition to expand the original health claim concerning the relationship between the consumption of soluble fiber from certain foods and reduced coronary heart disease (CHD). The current petition requests that 21 C.F.R.101.81 be expanded to include barley β-glucan soluble fiber and barley foods containing β-glucan soluble fiber as eligible sources of β-glucan soluble fiber.

The enclosed petition and binders contain the following information:

- Evidence that demonstrates our fulfillment of the health claim requirements set forth in 21 C.F.R. 101.14 to permit a health claim for the relationship between barley and CHD;
- Summary of scientific evidence demonstrating significant scientific agreement on the cholesterol lowering efficacy of whole-grain and pearled barley foods;
- Evidence of the physical, chemical and functional equivalence of barley and oat β-glucan soluble fiber.

Should the U.S. Food and Drug Administration (FDA) grant preliminary approval of this health claim petition, the NBFC also request that FDA grant an *Interim Final Rule,* by which eligible barely products containing β-glucan soluble fiber could carry the Barley Soluble Fiber and CHD health claim during the period after FDA's preliminary approval and prior to its publication of a Final Rule.

2004P-0512 CP1

Please do not hesitate to contact the NBFC or our consultant if further discussion or information is required. For this reason, questions, phone calls and communication may be addressed to the undersigned at the address provided.

Respectfully,

Doug Scoville, Chairman
National Barley Foods Council

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Enclosures: Petition Binder
Appendices Binder
8 Reference Folders
Copy of Petition and Appendices in Folders
1 Cd-rom with 1) Petition + Appendices in MSWord 2000
2) PDF files of some of the references

PETITION FOR UNQUALIFIED HEALTH CLAIM:

BARLEY B-GLUCAN SOLUBLE FIBER
AND BARLEY PRODUCTS
CONTAINING
B-GLUCAN SOLUBLE FIBER
AND
CORONARY HEART DISEASE

SUBMITTED TO THE

FOOD AND DRUG ADMINISTRATION

SEPTEMBER 22, 2003

PETITIONERS:

NATIONAL BARLEY FOODS COUNCIL

Barley Health Claim Petition

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I. INTRODUCTION

A. Overview of Petition

Pursuant to section 403(r)(4) of the Federal Food, Drug and Cosmetic Act (FFDCA) the National Barley Foods Council (NBFC) submits this health claim petition regarding the relationship between the consumption of soluble fiber from certain foods and the reduced risk of coronary heart disease (CHD). This petitions requests that the "Soluble Fiber from Certain Foods and Coronary Heart Disease Health Claim" (21 CFR 101.81) be amended to include soluble fiber from barley and barley products.

B. Background

The 1990 Nutrition Labeling and Education Act (Public Law 101-535) was signed into law on November 8, 1990. This new law changed the previous act in a number of important ways including confirming the FDA's authority to regulate health claims on food labels and in food labeling. In 1993 the agency issued several new regulations that implemented the health claim provisions of the 1990 amendments. Among those were § 101.14 (21 CFR 101.14) which set out the rules for authorization and use of health claims and § 101.70 (21 CFR 101.70) which established a process for petitioning the agency to authorize health claims about a substance-disease relationship and set out the types of information that any such petition must include (FDA 1993a). That same year (FDA 1993b), the agency authorized a health claim relating consumption of fruits, vegetables and grain products that contain fiber, particularly soluble fiber, to reduced risk of CHD (21 CFR 101.77). In the preamble to this ruling the FDA solicited submission of product specific health claims from manufacturers or interested groups that can document through appropriate studies that their food is effective in lowering LDL-cholesterol and has no adverse on other heart health risk factors. In response to this challenge several petitions have been submitted to the agency documenting the heart health benefits of specific soluble fiber sources (FDA 1996, FDA 1997b, FDA 2002).

The FDA (1997a) authorized the first food substance specific heart health claim in 1997. In 21 CFR 101.81, the agency authorized a health claim associating the consumption of diets low in saturated fat and cholesterol that included soluble fiber (β-glucan) from oats and the reduced risk of CHD. The petitioner, Quaker Oats, had requested the health claim for oat bran and oat meal. However, in the course of evaluating the available scientific evidence regarding the consumption of oat products and the reduced risk of CHD, the FDA concluded that the soluble fiber (β-glucan) found in oats was the component primarily responsible for the association between consumption of whole oat products and oat bran and the reduced risk of CHD. This determination was based upon two key observations. First, there was a dose response relationship between the amount of β-glucan soluble fiber consumed and the reduction in LDL-cholesterol and total serum cholesterol. Second, a reasonable β-glucan soluble fiber intake of 3 g or more per day was effective in reducing LDL-cholesterol and total serum cholesterol. Thus, on the basis of the scientific evidence, the agency stated (FDA 1997a) "FDA, therefore, concludes that it is appropriate to change the food substance that is the subject of this authorization for claims from oat bran and rolled oats to β-glucan soluble fiber from whole oats."

The original petition by the Quaker Oats Company only requested authorization of the health claim for rolled oats and oat bran. However, based on the comments and scientific data submitted to the FDA, the claim, in the final rule (FDA 1997a) was expanded to include whole oat flour. The FDA (2002) distinctly summarized this position when it stated "We were persuaded that the clinical data showing the positive effects of consuming whole oat flour foods on blood cholesterol, and comments showing the compositional similarities between whole oat flour and rolled oats provided sufficient evidence for us to conclude that whole oat flour has the same effects relative to reduced risk of CHD as do oat bran and rolled oats. Further, this conclusion was corroborated by evidence from the rodent intestinal contents studies. These studies demonstrate that the beta-glucan soluble fiber from whole oat flour retains the same level of viscosity in the rodent digestive tract as does that from rolled oats (62 FR3584 at 3686)." Thus, the three eligible sources of beta glucan soluble fiber for the whole oat heart health claim 'were determined to be oat bran, rolled oats and oat flour.

Some comments to the FDA's proposed rule suggested that other sources of β-glucan be determined to be eligible for the heart health claim. The FDA acknowledged the possible benefits of consuming (β-glucan) soluble fiber from other sources but stated that the subject of the rulemaking was oatmeal and oat bran and their effect on the risk of CHD. Additionally, the agency pointed out that they had not had an opportunity to review the totality of the evidence for these other sources of soluble fibers. However, the FDA (1997a) stated "Nonetheless, the agency recognizes that it is likely that consumption of other sources of β-glucan soluble fiber in addition to those that are the subject of this rule making will affect blood cholesterol levels. For this reason, and for reasons described elsewhere in this document in response to related comments about other soluble fibers, FDA is adopting a final rule that is structured so that it can be amended to establish a framework that will accommodate claims for other sources and types of soluble fibers and the risk of CHD".

On February 18, 1998 in response to a petition by the Kellogg Co., the FDA (1998) utilized this structure when they announced their decision to amend the regulation that authorized a health claim on soluble fiber from whole oats and the risk of CHD to include soluble fiber from psyllium seed husk.. As a result of this change, the agency revised the inclusion language for § 101.81 from *"Health claims: soluble fiber from whole oats and the risk of coronary heart disease (CHD)"* to *"Health claims: Soluble fiber from certain foods and the risk of coronary heart disease (CHD).*

Recently, in response to a petition jointly filed by the Quaker Oats Co. and Rhodia Inc., the agency announced it's decision (FDA 2003) to amend the regulation authorizing a health claim on the relationship between beta-glucan soluble fiber from whole oat sources and reduced risk of CHD by adding another source of beta-glucan to those eligible to receive the heart health claim. The petition had requested the "Soluble Fiber from Certain Foods and Coronary Heart Disease Health Claim" (21 CFR 101.81) be expanded to include their Oatrim (known as Oatrim BetaTrim™). The substance group Oatrim (BetaTrim™) has a β-glucan content of 4 to 25% and is manufactured by one of two controlled hydrolysis processes – an acid/base method or an enzymatic (alpha-amylase) method. However, the FDA decided, based on it's review of the scientific data, to limit the amendment to one specific class of oatrim. The agency (FDA 2002) stated "The substance tested in the clinical cholesterol-lowering efficacy study did not include acid-base hydrolyzed products or products with beta-glucan content exceeding 10 percent.

Therefore, the agency is not including substances other than oatrim, defined as the beta-glucan containing soluble fraction from alpha-amylase hydrolyzed oat bran or whole oat flour with a beta-glucan soluble fiber content up to 10 percent (dwb) and not less than that of the starting material (dwb), as an eligible source of beta-glucan for this health claim"

Expansion of 21 CFR 101.81 to include oatrim is an extremely important change from both a regulatory and scientific point of view. When the agency decided to make beta-glucan soluble fiber the substance of the original heart health claim and not oat bran or oatmeal they determined that beta-glucan was the primary (but not the only) component in whole oats responsible for the level of reduction of blood total and LDL-cholesterol. The FDA limited eligible products to oat bran, oatmeal and whole oat flour (which was included only after thorough examination of the scientific data submitted during the comment period). Finally, the agency very carefully specified the β-glucan and total fiber contents of oat bran, oatmeal and whole oat flour. The eligible substance definitions (FDA 1997a) were as follows:

"Oat bran. Oat bran is produce by grinding clean oat groats or rolled oats and separating the resulting oat flour by suitable means into fractions such that the oat bran fraction is not more than 50 percent of the starting material and provides at least 5.5 percent (dry weight basis (dwb)) β-glucan soluble fiber and a total dietary fiber content of 16 percent (dwb), and such that at least one third of the total dietary fiber content is soluble fiber."

"Rolled oats. Rolled oats, also know as oatmeal, produced from 100 percent dehulled, clean oat groats by steaming, cutting, rolling, and flaking, and provides at least 4 percent (dwb) of β-glucan soluble fiber and a total dietary fiber content of at least 10 percent"

Whole oat flour. Whole oat flour is produced from 100 percent dehulled, clean oat groats by steaming and grinding such that there is no signicant loss of oat bran in the final product, and provides at least 4 percent (dwb) β-glucan soluble fiber and a total dietary fiber content of at least 10 percent (dwb)."

Basically, these are the whole grain forms of oats and include all of the macro and micro-nutrients found in oat products. In contrast oatrim contains few of the macro and micro-nutrients found in whole oat products other than beta-glucan soluble fiber. Table 1 illustrates the differences in composition between oatrim and the classical whole oat fractions. Oatrim is defined as follows (FDA 2002):

"Oatrim. The soluble fraction of alpha-amylase hydrolyzed oat bran or whole oat flour, also known as oatrim. Oatrim is produced from either oat bran as defined in § 101.81 paragraph (c)(2)(ii)(A)(1) or whole oat flour as defined in § 101.81 paragraph (c)(2)(ii)(A)(3) by solubilization of the starch with in the staring material with an alpha-amylase hydrolysis process, and then removal by centrifugation of the insoluble components consisting of a high portion of protein, lipid, insoluble dietary fiber, and the majority of the flavor and color components of the starting material. Oatrim shall have a beta-glucan content up to 10 percent (dwb) and not less than that of the starting material."

The data in Table 1 clearly shows that compositionally, with the exception of β-glucan soluble fiber, oatrim bears little resemblance to the other oat products. In this regard, the agency stated (FDA 2002) "Oatrim differs from oat bran and whole oat flour in that, in the manufacturing of oatrim, much of the starch present in the whole oat flour or remaining in the oat bran has been converted to soluble amylodextrins, and non-water soluble components of the starting milled oat products are removed by centrifugation. However like oat bran, the oatrim fraction produced

Table 1. Typical Macronutrient Composition of Oatrim, Rolled Oats, Oat Bran and Whole Oat Flour (Per 100g)[1]

Nutrient	Oatrim (BetaTrim™)	Rolled Oats	Oat Bran	Whole Oat Flour
Calories (kcal)	337	389	397	384
Calories from fat (kcal)	6.3	62.1	63.3	62.1
Total Fat (g)	0.7	6.2	7.0	6.9
Saturated Fat (g)	0.3	1.2	1.3	1.3
Cholesterol (mg)	0	0	0	0
Total Carbohydrate (g)	89.6	66.2	66.2	67.3
Dietary Fiber (g)	6.2	10.3	15.9	10.5
β-glucan (g)	4.0-6.0	5	7.7	4
Protein (g)	1.5	16.9	17.3	13.7

[1]Data from Table 1 Oatrim (BetaTrim™) Health Claim Petition dated April 5, 2001 submitted to the FDA by The Quaker Oats Company and Rhodia Inc.

from the manufacturing methods of Inglett and Newman, 1994 retains most of the beta-glucan soluble fiber and fiber-associated substances found in whole oat products." This information in conjunction with the clinical data further documents the cholesterol lowering properties of β-glucan soluble fiber and shows that these properties can be maintained and expressed in purified substances that have been carefully managed during processing. Furthermore, it indicates that the total dietary fiber requirement imposed to assure the fidelity of the other eligible oat products is not a critical factor in determining the cholesterol lowering properties of β-glucan soluble fiber from oat products.

With this petition, the National Barley Foods Council proposes that 21 CFR 101.81 be amended to include barley as a source of β-glucan soluble fiber associated with reduced risk of coronary heart disease. The Council further proposes that whole grain and milled barley products such as dehulled or hulless barley, pearl, flakes, grits, meal, flour, β-glucan enriched meal or flour fractions, and bran be determined as eligible sources of barley β-glucan soluble fiber. There already exists considerable scientific agreement that barley is a source of viscous fiber (Jenkins et al 2002) and, as such, is recommended by the National Cholesterol Education Panel (NCEP 2002) as one of the therapeutic dietary options for lowering LDL-cholesterol. The NCEP recommendations are approved and published by the National Heart, Lung and Blood Institute of the National Institute of Health. These recommendations are clearly based on the human and animal feeding studies that demonstrate the efficacy of barley β-glucan soluble fiber in reducing elevated blood cholesterol levels in mild to moderate hypercholesterolemics. These studies and supporting scientific evidence are presented in this petition for consideration by the agency for the establishment of an amended health claim. Furthermore, scientific evidence are presented that establish the bioequivalence of oat and barley β-glucan soluble fiber.

Expanding the heart health claim in 21 CFR 101.81 to include barley (β-glucan) soluble fiber will enhance the consumer's ability to incorporate "soluble fiber" into the daily dietary regime. Barley products are typically used in a wide variety of eating occasions in addition to breakfast. The (β-glucan) soluble fiber content of traditional barley products is equal to or greater than that of whole oat products. Further, barley has a significantly lower fat content. Barley's lower fat content (< 3%) provides increased flexibility to product formulators attempting to enhance product palatability while still meeting the health claim eligibility requirements for finished food products. Additionally, some specialty barley varieties have β-glucan contents greater than or equal to oat bran. These varieties are available for commercial production and provide some unique opportunities for the development of heart healthy products. These advantages and other benefits are detailed later in this petition.

Attached hereto, and constituting a part of this petition, are all of the items specified in 21 CFR § 101.70 (d). The proposed text of the model claim is set forth in section V of this petition.

II. PRELIMINARY REQUIREMENTS

A. Barley β-glucan soluble fiber and barley products containing β-glucan soluble fiber are associated with reduced risk of coronary heart disease, a disease for which the U. S. population is at risk [(21 CFR 101.14(b)(i)].

Coronary heart disease (CHD) has a tremendous financial impact upon our economy and a huge impact upon the quality and duration of life for individuals afflicted with this condition. It is the leading cause of death in the U. S. (Hoyert et al 1999; CDC 1999). Additionally, CHD causes significant reductions in productivity and increases in morbidity as measured by the levels of non-fatal myocardial infarction and angina observed in the U. S. population (AHA 1999). Recently, the agency (FDA 2002) stated "While age-adjusted CHD mortality rates in the United States had been steadily decreasing since approximately 1960, recent evidence has suggested that the decline in CHD mortality has slowed. Cardiovascular disease accounts for more than 900,000 U.S. deaths annually and has been recognized as the dominate cause of death in the United States for at least 50 years". Thus, the FDA concluded "CHD is a disease for which the U.S. population is at risk."

Three major modifiable risk factors have been identified for CHD; smoking, elevated blood pressure and high cholesterol levels. Specifically in relation to this petition, elevated total cholesterol and LDL cholesterol levels have been established as major modifiable risk factors for CHD (NCEP 2002). The potential benefits of serum cholesterol reduction are very significant. It has been estimated that every 1% decrease in serum cholesterol would provide a 2-3% reduction in the observed rate of CHD (NCEP 2002).

In the total U. S. population 20% of adults are estimated to have high total cholesterol (>240 mg/dl); another 31% have borderline high cholesterol levels (Sempos et al 1993). The incidence increases significantly for adults aged 40 and over. The third National Health and Nutrition Examination Survey (NHANES III) showed that 65% of all adults age 40 and over have a borderline high serum cholesterol of 200-239 mg/dl (Samuel et al 2000).

Scientific studies have clearly shown that dietary modifications are an effective approach to reducing the risks of CHD in affected individuals and the population as a whole. In this regard, increased intake of certain soluble dietary fibers has been identified as an effective dietary approach for reducing both LDL-cholesterol and total serum cholesterol. Unfortunately, the mean total dietary fiber intake for the U.S. population two years and older is just 16 g/day compared to the recommended level of 25-30 g/day (Enns et al 1997). The effectiveness of dietary oat β-glucan soluble fiber and psyllium soluble fiber in reducing the risk of CHD by reducing the serum levels of LDL-cholesterol and total cholesterol is well documented. These two soluble fiber sources have been the subject of previous FDA rulings (see 21 CFR 101.81;

FDA 1997a; FDA 1998; and FDA 2003). Barley products are also an excellent source of β-glucan soluble fiber and can be readily incorporated into many dietary regimes. The scientific evidence presented in Section III, of this petition, documents barley β-glucan soluble fiber's physical and chemical properties and effectiveness in reducing LDL-cholesterol and total serum cholesterol. Thus, this petition meets the requirements of 21 CFR 101.14(b)(1) since it addresses a major public health issue for the U.S. population.

B. Barley β-glucan soluble fiber and barley products containing β-glucan soluble fiber are either foods or ingredients of food that provide nutritive value and comply with the requirements of 21 CFR 101.14(b)(3)(i).

Barley products that contain β-glucan soluble fiber, including dehulled or hulless barley and pearl, flakes, grits, meal, flour, β-glucan enriched meal or flour fractions, and bran derived from either dehulled or hulless barley, contribute taste, aroma and/or nutritive value as foods and food ingredients. Typical barley processing is described in Appendix I along with product definitions compiled by the American Association of Cereal Chemists (2000). The aforementioned barley products are excellent sources of energy, protein, vitamins, minerals and soluble and insoluble fiber. The β-glucan content of common barley and barley products is equal to or greater than that found in whole oat products. Additionally, some commercial hulless barley cultivars contain β-glucan levels greater than most commercial oat bran products. This latter fact provides some unique product development opportunities. Nutritional testing shows that the cholesterol lowering attributes of barley β-glucan are retained in the final food products. Further, consumption of barley β-glucan soluble fiber at the proposed levels may result in the reductions in LDL-cholesterol and total serum cholesterol necessary to justify the petitioned claim. The nutritive values of barley grain, pearled barley and flour/meal are set forth in Table 2. The data in this table clearly demonstrate that barley products containing β-glucan soluble fiber meet the requirements set forth in 101.14(b)(3)(i).

Table 2. Macronutrient Composition of Barley

Component	Grain[a]	Pearl,raw[b]	Flour[b]
	-------------g/100g, 10% moisture basis-----------		
Carbohydrates	70-75	77.7	76.1
Starch	54-59	62.1	65.8
Fiber	12.0-18.9	15.6	10.3
Arabinoxylan	4.4-7.8		
β-glucan	3.6-6.1	5.1[c]	5.6[c]
Cellulose	1.4-5.0		
Simple carbohydrates (glucose, fructose, Sucrose and maltose)	0.41-2.9		
Oligosaccharides (raffinose, fructosans)	0.16-1.8		
Lipids	2-3	1.2	1.6
Proteins	8-15	9.9	10.7
Albumins and globulins	3.5-4.5		
Hordeins	3-5		
Glutelins	3-5		
Minerals	2-3	0.69	0.76
Other	5-6	1.1	1.0

[a]Taken from MacGregor and Fincher (1993).
[b]Values, except β-glucan, taken from USDA National Nutrient Database for Standard Reference, Release 15 - http://www.nal.usda.gov/fnic/cgi-bin/nut_search.pl.
[c]Average from published data, see Table 11 – pearl barley and meal.

C. Barley β-glucan soluble fiber and barley products containing β-glucan soluble fiber are safe and lawful [21 CFR 101.14(b)(3)(ii)].

Barley, both its hulled and hulless forms, has a long history of use as human food prior to 1958. It was cultivated for food use as far back as 7000 years ago (Clark 1967) and preceded wheat as a food grain in ancient Egypt (Darby et al, 1977). Barley was a major food staple in many developing European and Asian civilizations and particularly important at higher altitudes where other grains have difficulty growing. In mountain regions of Ethiopia, Peru and Tibet barley can account for 60% of a populations plant food (NRC 1996).

Today, barley and barley products in the U.S. including dehulled or hulless barley and pearl, flakes, grits, meal, flour, β-glucan enriched meal or flour fractions, and bran derived from either dehulled or hulless barley, are used in a variety of breakfast cereals, soups, stews, bakery products and baby foods as well as a number of traditional ethnic dishes like miso (Japanese), risotto (Italian) and kasha (Russia and Poland). As a point of trivia, cream of barley soup was on the Titanic's first class dining room final dinner menu on Sunday, April 14, 1912 (Houston 2003).

The highest level of barley food consumption in the U.S. occurred in 1947; 6.7 lb/person/year, almost equal to oat (Economic Research Service 2002). Since that time, U.S. per capita consumption has declined to less than 1 lb/person/year. However, according to the FAO (2003), in 1961 per capita consumption was 141.2 and 190.7 lbs in Korea and Morocco, respectively. The highest per capita food consumption of barley as recently as 2001 has been in Morocco (92.6 lbs) followed by over 26 lbs/person/year in eight other countries on 3 continents.

The aforementioned barley products when used as a food or food ingredient at levels necessary to justify the petition claim are safe and lawful under the FFDCA (21 CFR 101.14(b)(3)(ii)). GRAS substances are those whose use is generally recognized by experts as safe, based on their extensive history of use in food before 1958. Barley and the β-glucan soluble fiber contained in barley has a long history of use as a food and food ingredient, and is generally recognized as safe (21 CFR 170.30(d)).

III. SUMMARY OF SCIENTIFIC EVIDENCE

A. Overview of Scientific Data

The scientific data presented in this section summarizes all human and animal studies that examine the relationship between consumption of barley containing β-glucan soluble fiber and CHD risk factors. Additionally, data is presented on the physical and chemical structure of barley β-glucan soluble fiber.

Two previous petitions for health claims on the relationship between β-glucan soluble fiber from oats and CHD have clearly demonstrated the efficacy of oat β-glucan soluble fiber in reducing the risk of CHD (FDA 1997, 2002). The agency concluded that "the type of soluble fiber found in whole oats, i.e., β-glucan soluble fiber, is the component primarily responsible for the hypocholesterolemic effects associated with consumption of whole oat foods as part of a diet that is low in saturated fat and cholesterol". Further, their conclusion was based on "evidence that that there is a dose response between the level of β-glucan soluble fiber from whole oats and the level of reduction in blood total- and LDL-cholesterol". The human and animal data presented in this document support similar conclusions for β-glucan soluble fiber from barley and the physical and chemical comparative data demonstrate a strong similarity between barley and oat β-glucan soluble fiber .

The human clinical trial data clearly demonstrates that consumption of barley β-glucan soluble fiber is an effective dietary approach for lowering LDL-cholesterol and total serum cholesterol. The observed decreases in LDL-cholesterol and total serum cholesterol associated with consumption of barley β-glucan soluble fiber are equal to the changes brought about by dietary oat β-glucan soluble fiber. Similarly, as seen with consumption of oat products, the desirable HDL-cholesterol is unchanged in individuals consuming barley products. Finally, the decreases in serum cholesterol reported in appropriately designed barley clinical trials are consistent with the dose response mechanism observed in the oat clinical trials. These data and supporting comparisons between barley and oats in animal trials will establish that there is "significant scientific agreement" regarding the efficacy of barley β-glucan soluble fiber consumption in reducing the risk factors associated with CHD.

The human data presented in this petition supports the conclusion that consumption of 3 grams of barley β-glucan soluble fiber per day results in clinically and statistically significant reductions of LDL-cholesterol and total serum cholesterol (greater than or equal to 5% of the initial value). This consumption target is consistent with the 3g/day target authorized for oat β-glucan soluble fiber (amount required to achieve meaningful cholesterol reduction in the U.S. population). Equivalent dietary target levels are a logical scientific conclusion based on the physical and chemical similarity of barley and oat β-glucan soluble fiber and the similar human and animal responses (changes in lipid profiles) to consumption of the qualified barley and oat products.

B. Soluble Fiber from Barley Foods May Reduce Risk of Coronary Heart Disease

Eight human clinical and 48 animal trials have studied the change in lipid status (or associated metabolites) brought about by the consumption of barley products containing β-glucan soluble fiber. These studies include barley processed by dry-milling (including meal or flour, flakes, bran and pearl) and wet-milling (high β-glucan extracts). Research on products made from barley that do not contain β-glucan soluble fiber, including the oil and brewer's spent grains (BSG), are presented at the end of this section to provide a more comprehensive understanding of barley and barley derived products and their role in reducing the risk of CHD.

1. Comparisons with Barley in Human Studies

Barley is an excellent source of β-glucan and barley foods containing β-glucan soluble fiber have been included as a dietary intervention in eight human clinical trials measuring changes in lipid profiles and risk reduction for CHD (Table 3). β-glucan containing barley products, including flour (whole grain flour, pearled flour, and sieved flour), bran, flakes, and pearl barley, consistently reduced total and LDL cholesterol and either increased or had no effect on HDL cholesterol. The design and merits of these studies are discussed below.

Three studies included hypercholesterolemic subjects and barley food interventions as part of a Step 1 diet (Behall et al 2003; Behall et al 2004; Pins et al 2000). Of these three, two studies had a randomized controlled design that evaluated the impact of two levels of barley soluble fiber on

Table 3. Summary of Human Clinical Trials Utilizing Barley Foods Containing β-glucan Soluble Fiber as a Dietary Intervention to Reduce Risk of CHD[a].

Study	Subjects/ Initial TC	Diet Intervention	Methods	Results[b]
Behall et al 2004	18 male 235 mg/dl	Barley Pearl, Flakes, Sieved Flour Average – 5.0% SDF Brown rice / whole wheat (BR/WW)	2 wks NCEP Step 1 diet; then 15 wk crossover with Latin Square design; 3 trts: 0, 3g, 6g barley soluble fiber + NCEP Step 1 diet *Barley SDF g/day:* Low = < 0.5 (BR/WW) Mid = 3g (BR/WW + barley foods) High = 6g (barley foods)	Barley Mid vs. Step 1 diet – TC: - 24.2 mg/dl (- 10.8%) LDL: - 23.1 mg/dl (- 14.6%) HDL: + 1.4 mg/dl (+ 3.7% ns) Barley High vs. Step 1 diet – TC: - 37.1 mg/dl (- 16.6%) LDL: - 33.8 mg/dl (- 23.8%) HDL: + 2.4 mg/dl (+ 7.3%)
Behall et al 2003 - abstract	7 male 206 mg/dl 9 female/pre-M 209 mg/dl 9 female/post-M 233 mg/dl	Barley Pearl, Flakes, Sieved Flour Average – 5.0% SDF Brown rice / whole wheat (BR/WW)	2 wks NCEP Step 1 diet; then 15 wk crossover with Latin Square design; 3 trts: 0, 3g, 6g barley soluble fiber + NCEP Step 1 diet *Barley SDF g/day:* Low = < 0.5 (BR/WW) Mid = 3g (BR/WW + barley foods) High = 6g (barley foods)	Barley Mid/High vs. Step 1 diet in men & post-M females– TC/LDL: -10% Barley Mid/High vs. Step 1 diet in pre-M females– TC/LDL: -5%
Ikegami et al 1996	*Trial 1:* 5 male 207 mg/dl *Trial 2:* 20 male 278 mg/dl *Trial 3:* 7 female 250 mg/dl	Pearled barley 13.6% TDF calculated, dwb Normal diet - rice	all studies: 280 g/day barley/rice 50:50 mix = 6.1 g TDF/day from barley *Study 1:* 6.1 g/d TDF from barley for 4 weeks *Study 2:* 6.1 g/d TDF from barley for 2 weeks *Study 3:* 6.1 g/d TDF from barley for 2 weeks No significant dietary changes in saturated fat or total energy	*Study 1:* Barley vs. baseline – TC: - 11.3 mg/dl (-5.4% ns) LDL: - 11.6 mg/dl (-8.2% ns) HDL: - 2.7 mg/dl (- 5.8% ns) *Study 2:* Barley vs. baseline – TC: - 27.5 mg/dl (- 9.9%) LDL: - 23.9 mg/dl (-12.8%) HDL: + 0.4 mg/dl (+ 0.8% ns) *Study 3:* Barley vs. baseline – TC: - 24.8 mg/dl (- 9.8%) LDL: - 23.2 mg/dl (-13.4%) HDL: - 0.7 mg/dl (- 1.3% ns)

Table 3 . continued

Study	Subjects/ Initial TC	Diet Intervention	Methods	Results
McIntosh et al 1991	21 male 241 mg/dl	Barley – bran 50% extraction – 4.9% BG flakes - 4.4% BG Whole wheat flour	Randomized crossover, 3 wk baseline, 2 - 4 wk periods with no rest; *BG g/day:* barley = 8.0, wheat = 1.5 *TDF g/day:* barley = 38.4, wheat = 38.4 *Fat % E:* barley = 34.9 wheat = 31.9	Barley vs. baseline – TC: -5.0 mg/dl (-2.1% ns) LDL: -1.9 mg/dl (-1.2% ns) HDL: no change Body Weight: + 1.8 lb (+1% ns) Barley vs. wheat – TC: -15.1 mg/dl (-6.0%) LDL: -12.8 mg/dl (-6.8%) HDL: + 0.7 mg/dl (+2.5% ns)
Narain et al 1992	5 male 1 female 214 mg/dl	Barley flour - wholegrain Normal diet - wheat/rice	4-wk crossover, 1 wk rest; *Cereal g/day:* Barley = 100 barley + 150 wheat/rice Normal = 250 wheat/rice	Barley vs. baseline – TC: +2.0 mg/dl (+ 0.9% ns) HDL: +14.8 mg/dl (+29.2%) Body Weight: no change
Newman et al 1989a	14 male 177 mg/dl	Barley flour - whole grain waxy hulless barley- 9.6% BG, 32.6% EDF Wheat bran/flour – 24.3% EDF	Randomized parallel, 4 weeks *EDF g/day:* barley = 42 wheat = 42 *Fat % E:* barley = 42 initial to 35 end wheat = 35 initial to 34 end	Barley vs. baseline – TC: -5.3 mg/dl (-3.0% ns) LDL: -6.7 mg/dl (-5.6% ns) HDL: + 2.2 mg/dl (+6.9% ns) Body Weight: -1 lb (-0.5% ns) 2 subjects with TC ≥210mg/dl TC: -24.5 mg/dl (-11.3% no statistic) LDL: -25.5 mg/dl (-16.0% no statistic) Barley vs. wheat – TC: -24.3 mg/dl (-12.3%) LDL: -18.9 mg/dl (-14.3%) HDL: - 4.3 mg/dl (-10.5% ns)

Table 3. continued

Study	Subjects/ Initial TC	Diet Intervention	Methods	Results
Newman et al 1989b	22 256 mg/dl	Barley flour - whole grain waxy hulless barley Oatmeal flour	Randomized parallel, 6 weeks *TDF intake g/day:* barley diet = 40 oat diet = 27	Barley vs. baseline – TC: -12.0 mg/dl (- 4.7%) LDL: -24.0 mg/dl (-13.9%) HDL: + 5.0 mg/dl (+10.2%) Body Weight: - 0.2 lb (ns) Oat vs. baseline - TC: -12.0 mg/dl (-4.8%) LDL: -11.0 mg/dl (-7.0%) HDL: - 6.0 mg/dl (-9.5%) Body Weight: + 0.1 lb (ns)
Pins et al 2000 - abstract	60 246 mg/dl	Pearled barley flour Barley pearlings Wheat flour	6 wks AHA Step 1 diet, then- Randomized, parallel, 4 weeks, 3 trts. 4-75 g muffins/day	Pearled barley flour vs. baseline – TC: -7.7% LDL: -8.2% Barley pearlings vs. baseline – TC, LDL,HDL - no change

[a] Abbreviations: CHD = coronary heart disease; TC = total cholesterol; LDL = low density lipoprotein (cholesterol); HDL = high density lipoprotein; M=menopause; TDF = total dietary fiber; IDF = insoluble dietary fiber; SDF = soluble dietary fiber; NCEP = National Cholesterol Education Program; BG = β-glucan; dwb = dry wt basis ; EDF=estimated dietary fiber; %E = % energy; Sat. Fat % E = % energy from saturated fat.
[b] All changes reported are significant ($p < 0.05$) unless followed by ns (nonsignificant);

cardiovascular risk factors (Behall et al 2003, Behall et al 2004). Both studies took place at the USDA Beltsville Human Nutrition Research Center where free living subjects ate a controlled Step 1 diet for 2 weeks prior to 3 periods (5 weeks each) in which 20% of the energy was replaced with a whole grain intervention: 1) whole wheat and brown rice, 2) ½ whole wheat/brown rice and ½ barley foods and 3) only barley foods. The three intervention diets, having low (0), mid (3g) and high (6g) levels of barley soluble fiber, respectively, were consumed in a 15 week crossover Latin Square design. Barley foods, including hot cereal, pancakes, granola, pilafs, muffins, cakes, and cookies were prepared from a combination of pearl barley (75% extraction), pearl barley flakes and flour made by grinding and sieving the pearl barley. The barley raw materials used in the diets had an average soluble fiber content of 5% and the β-glucan content ranged from 4.9 to 7.3% (Fastnaught and Hadley 2002; unpublished report to the NBFC in Appendix 3). All diets were identical with the exception of the increase in soluble fiber in the two diets containing barley products.

In the first study (Behall et al 2004) all but two of the eighteen hypercholesterolemic men maintained a stable weight during the 15 weeks, thus the data was statistically analyzed with and without the two subjects that lost weight and the conclusions were almost identical. Subjects had significantly lower total (-10 to -16%) and LDL-cholesterol (-14 to -23%) and slightly higher HDL-cholesterol when consuming the whole grain diets compared to the baseline Step 1 diet. The diet with 6 g of soluble fiber from barley significantly reduced total and LDL-cholesterol more than the other two diets (-8.8% and -10.9%, respectively) suggesting a dose response to barley soluble fiber similar to oat β-glucan soluble fiber. This diet also resulted in a significant 7.3% increase in HDL cholesterol.

The whole wheat/brown rice diet was selected as a low soluble fiber control because of the similarity in appearance between pearl barley and brown rice which facilitated blinding of the treatments. However, no difference was detected between this diet which had no barley and the diet with 3 g of soluble fiber from barley. Both of these diets reduced total cholesterol about 10% and LDL cholesterol 14%. This is the first time this has been reported for a whole grain diet that included whole wheat and brown rice. Whole wheat has been used as a control or low soluble fiber treatment in numerous lipid response studies and consistently has exhibited little or no capability to lower cholesterol (Shinnick et al 1991). A single human clinical study that included brown rice reported no reduction in cholesterol in normocholesterolemic men (Miyoshi et al 1986), but there is evidence that rice bran or rice oil may have some cholesterol lowering ability (Kahlon and Chow 1997). Kahlon and Chow (2000) reported that the lipid responses of hamsters consuming brown rice were not different from hamsters consuming cellulose. However, Marsono et al (1993) reported that brown rice fed to pigs produced the greatest digesta mass along the entire large bowel compared to white rice and rice bran and significantly higher volatile fatty acids in the median and distal colon. But they reported that only a diet combining rice bran and rice oil lowered cholesterol. While the brown rice used in this study had a higher lipid content than the wheat or barley, the level is probably not high enough to explain the observed reductions.

An initial 4% decrease in total cholesterol was reported for all the subjects in this study as a result of the 2 week Step I equilibration diet. All of the subjects remained on this diet throughout the study. It is likely that some of the additional 10% reduction in total cholesterol during the low and mid soluble fiber periods was due to the continuing effect of the Step 1 diet. A meta-analysis of 21 studies found that the Step I diet decreased total cholesterol about 10% (Yu-Poth et al 1999) but this was frequently associated with weight loss. In the oat and barley lipid studies, one of the objectives was to maintain a stable weight. Seven of the oat lipid studies included a pre-trial period on the Step 1 diet and used the Step 1 diet as a control (Beling et al 1991; Davidson et al 1991; Keenan et al 1991; Turnbull and Leeds 1987; Van Horn et al 1986; 1988; 2001). The decrease in cholesterol during the pre-trial period (ranging from 3 to 6 weeks) was reported in five of these studies and averaged 5.8% (varying from 3.6 to 10%). All of these studies reported no change in total cholesterol in the control subjects (Step 1 diet only) after an additional 4 to 12 weeks. It has been observed that in controlled studies where body weight is maintained, a decrease in total cholesterol is associated with a decrease in HDL cholesterol (NCEP 2002) and appears to be related to consumption of high levels of carbohydrates. In fact, this pattern was repeated in this study, i.e., a significant 10% decrease in HDL cholesterol was reported at the end of the 2 week Step I equilibration diet. But, surprisingly, during the whole grain interventions a small but significant increase in HDL and a decrease in triglycerides was reported for the weight stable subjects. This is not consistent with continuing affects of a Step 1 diet.

Thus, it is likely, that a portion of the 10% reduction in total cholesterol during the low soluble fiber period was associated with the intervention. When the barley replaced the whole wheat/ brown rice, the decrease was maintained. In fact, if you compare the cholesterol lowering effects of the mid and high levels of barley β-glucan to those predicted by the oat meta-analysis (Ripsin et al 1992) you'll find that the reductions achieved by the barley meet or exceed the reductions projected for oat β-glucan. Meta-analyses of oat products and lipid lowering (Ripsin et al 1992; Brown et al 1999) concluded that the effect size of 3 g of oat soluble fiber on total cholesterol would be -4.7 mg/dl. However, Ripsin et al modified this to -16 mg/dl when subjects initial cholesterol levels were greater than 229 mg/dl. The baseline cholesterol in this study was 235.7 mg/dl and the 10.8% decrease in total cholesterol observed in the mid barley soluble fiber group (3g) is equivalent to 24.2 mg/dl, about 50% greater than expected by the oat data. Additionally, the 16% decrease observed in the high barley soluble fiber group is equivalent to 38.8 mg/dl, a little more than double the value expected by Ripsin et al for 3g of oat soluble fiber. This level of cholesterol reduction by 6g of barley soluble fiber would be very surprising if indeed, 3g had no effect.

The second study by this group involved 18 females, 9 pre- and 9 post- menopausal, and 7 men (Behall et al 2003). The 7 men and 9 pre-menopausal women were moderately hypercholesterolemic (206 and 209 mg/dl, respectively) while the post-menopausal women were overweight and hypercholesterolemic (233 mg/dl). The design and foods consumed were identical to the first study. Preliminary results were reported at the 2003 FASEB meeting and the final results will be available when a manuscript has been submitted and accepted for publication. The preliminary results indicate that the mid and high barley soluble fiber diets lowered total and LDL cholesterol 10% in men and post-menopausal women and 4-5% in the pre-menopausal women. It was expected that the observed decreases would be lower than in the first study since the subjects baseline cholesterol was lower.

In the third study using hypercholesterolemic subjects following a Step 1 diet, Pins et al (2000) reported a 7.7% decrease in total cholesterol by subjects consuming four 75g muffins daily containing pearled barley flour. This was a randomized, parallel study with two other treatments, muffins made with wheat (the control) and muffins made with a barley bran. No changes in lipid response were observed in subjects consuming the barley bran muffins. The barley bran, a product of pearling, did contain soluble fiber but the amount was not reported for either diet. Complete data and soluble fiber content of diets will be available upon publication.

Two studies included both normo- and hypercholesterolemic subjects encouraged to follow their normal dietary patterns. In the first study (Ikegami et al 1996), pearled barley was used as the β-glucan soluble fiber source in the intervention diets. This research was separated into 3 different trials in which the subjects consumed an average of 280g/day of a prepared 50:50 mix of pearl barley and rice containing 6.1g total dietary fiber. Authors did not report soluble fiber or β-glucan but it is possible to estimate that β-glucan consumption was between 1.3 – 4.4g/day. This estimate was obtained by calculating the dry weight of barley consumed daily ((280g x 0.5) x (1-moisture)) to be 44.4g and assuming the β-glucan content could be anywhere from a minimum of 3% to a maximum of 10%. In trial 1, 5 male subjects having an average total cholesterol of 207mg/dl consumed the barley/rice mix for 4 weeks. A decrease of 5.4% in total and 8.2% in LDL-cholesterol was reported but was not significant. This is likely due to the small number of subjects. In trials 2 and 3, the number of subjects were increased and had higher initial levels of cholesterol. In both trials, a significant decrease in total (-9.8%) and LDL-cholesterol (-12.8 to -13.4%) was reported and HDL-cholesterol was unchanged. Additionally, VLDL-lipoprotein and TBA values (thiobarbituric acid – a measure of oxidation) were significantly decreased (-47%

and -27%, respectively) in the hyperlipidemic men in trial 2. Except for an increase in dietary fiber, nutrient intake did not change during the intervention period in trial 3 and, since barley is simply being substituted for rice that would normally be consumed, it is likely this would be the case in trials 1 and 2 also. It is unfortunate that trials 2 and 3 only lasted 2 weeks, however it is interesting to note that cholesterol levels observed at the end of the intervention period in trial 2 were the same 2 weeks post-intervention in men having the highest initial total cholesterol. This study provides excellent evidence that consumption of 44g of barley is able to reduce LDL-cholesterol and risk of CHD. While it is unfortunate we don't know the exact level of β-glucan consumed, we can estimate that it is close to the 3g level that is reported as the 'functional' level to derive benefits from oat β-glucan .

The second study utilized whole grain barley flour with 9.6% β-glucan ((Newman et al 1989a). The study used a randomized parallel design in which 14 subjects consumed barley or wheat products having equivalent amounts of estimated dietary fiber (42g/day). Neither soluble dietary fiber or β-glucan was reported for the products consumed. The subjects consuming a barley diet had significantly lower total and LDL-cholesterol (-12.3 and -14.3%, respectively) than subjects consuming a wheat diet during the same period. Subjects on the wheat diet had significantly higher total and LDL cholesterol when compared to their baseline levels while those on the barley diet did not change. Authors suggested that the small insignificant decreases observed in subjects on the barley diet as compared to the baseline diet may have been because most of the subjects did not have elevated levels of cholesterol. In two subjects with cholesterol over 210 mg/dl, total cholesterol was lowered by 11.3% and LDL-cholesterol by 16% when on the barley diet.

The three remaining human studies involved hypocholesterolemic subjects that were instructed to maintain their normal diet. One of these studies (Newman et al 1989b) was a follow-up to the study just discussed. Their previous results lead the scientists to screen participants for elevated cholesterol. In this randomized parallel study 22 subjects consumed equivalent amounts of barley or oat products. Daily total dietary fiber consumption (including the test products) was 40g for the barley diet and 27g for the oat diet. Unfortunately, neither soluble fiber or β-glucan were reported. Both the barley and oat diets significantly lowered total cholesterol about 4.7%. The barley diet lowered LDL-cholesterol 13.9%, almost twice as much as the oat diet (-7%). And, the barley diet significantly increased HDL-cholesterol by 10% while the oat diet lowered HDL-cholesterol by 9%. Diet records showed that the two groups were similar in energy and cholesterol intake but did not report fat consumption, though body weight did not change during the study. While this study is certainly deficient in not reporting the daily β-glucan or soluble fiber consumption, the positive results provided a basis to conclude that barley and oat β-glucan are similar in lowering cholesterol and the impetus for further studies to confirm this hypothesis. As with all of these studies, no ill effects were reported save for some bloating and gas which is to be expected when large quantities of fermentable fiber are quickly introduced into the diet.

The second study of this type utilized barley bran of 50% extraction and barley flakes in an intervention study with 21 hypercholesterolemic males in a randomized crossover design with whole wheat as the control diet (McIntosh et al 1991). The barley foods contained 4.4 - 4.9% β-glucan and the barley diet provided 8g of β-glucan daily. While on the barley intervention diet, subjects consumed a slightly higher percentage of fat (35% of energy) compared to the baseline

(31.3%) diet and all subjects gained a small amount of body weight though this was not considered significant. After 4 weeks on the barley diet, decreases in total and LDL cholesterol were not significant when compared to baseline values, but were 6% lower than when subjects consumed the whole wheat diet. HDL cholesterol was unchanged.

In a final, limited study, Narain et al (1992) reported total cholesterol was unchanged and HDL-cholesterol had increased 29% in 6 individuals that substituted 100g of whole barley flour for wheat or rice on a daily basis for 4 weeks in India. The individuals initial cholesterol was averaged 213 mg/dl, but ranged from 155 to 278 mg/dl. Unfortunately, the authors did not provide methodology on raw materials or processing nor did they measure LDL-cholesterol or report β-glucan or soluble fiber intake.

One additional study is discussed here because it provides data related to the mechanism of cholesterol reduction by barley and oat β-glucan. Lia et al (1995) studied bile acid and cholesterol excretion patterns in ileostomy patients consuming wheat, barley or oat bran breads for 2 days. The barley and oat bran breads contained 12.5g of β-glucan/day. Subjects had higher bile acid excretion while consuming the oat bran diet and higher cholesterol excretion while consuming the barley diet. But the trends were similar for the barley and oat diets compared to the wheat diet. Statistical significance was difficult to attain because of the extreme variation and low number of subjects (9). Perhaps more importantly, it was suggested that wet processing of this particular barley product may have reduced the functionality of the barley β-glucan (Sundberg et al 1995). Indeed, in a later study using the same material (Sundberg et al 1996), the molecular weight of the processed barley β-glucan was relatively low (1.65×10^5), though the molecular weight of the unprocessed material was never measured. Thus, this lower molecular weight barley β-glucan appeared to have some functionality but not equivalent to the oats.

The data supports the conclusion that barley foods containing β-glucan soluble fiber reduce LDL-cholesterol in humans. The most recent studies support this conclusion as well as provide required evidence of levels of barley β-glucan needed to achieve these results. The percent total cholesterol reduction achieved with 6g of soluble fiber from barley is consistent with the dose response curve for oat β-glucan soluble fiber that was plotted using the data from the Davidson et al (1991) study (Figure 1). Remember, barley foods providing 6g soluble fiber lowered cholesterol 16.6% compared to the baseline Step 1 diet and 8.8% compared to the whole wheat/brown rice diet (Behall et al 2004). Using the regression equation based on Davidson et al (1991) data, 6g of oat β-glucan is predicted to lower total cholesterol 8.6%. Thus, 6g of barley soluble fiber would be equivalent or better than 6g of oat β-glucan soluble fiber. This supports

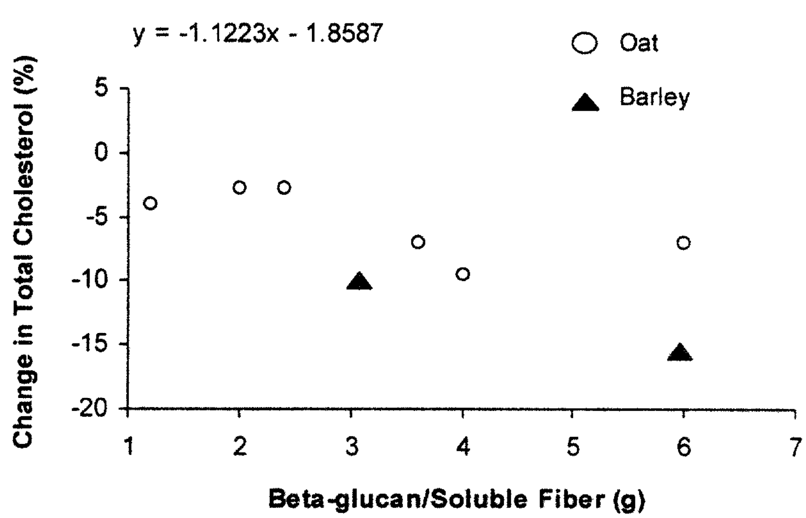

Figure 1. Change in total cholesterol in subjects consuming 6 levels of oat β-glucan soluble fiber (Davidson et al 1991) and 3 and 6g of barley β-glucan soluble fiber (Behall et al 2004).

our conclusion that barley and oat β-glucan are very similar and that 3g of barley β-glucan will reduce LDL-cholesterol on the average about 5% when consumed with a low fat, low cholesterol diet.

2. Direct Comparisons Between Barley and Oats in Animals

The lipid response to barley and oat consumption has been studied in 14 small animal trials that included either chicks, geese, rats or hamsters. The forms of barley include wholegrain flour, rolled flakes, meals, bran, extruded, and extracts, all containing β-glucan soluble fiber. In most of the studies, barley and oats reduced total cholesterol and LDL-cholesterol, though the response was not significant in a few cases.

β-glucan levels in the barley and oat diets were equivalent (±0.6%) in only 6 studies. These studies provide a mechanism for directly comparing the impact of barley and oat β-glucan on animal cholesterol levels. The investigations began with a series of studies jointly conducted by the USDA and Univ. of Wisconsin in 1980 that reported chickens consuming a diet containing 75% barley had lower cholesterol than chickens consuming 75% corn, wheat, oats or rye (Qureshi et al 1980). They associated lower levels of HMG-CoA reductase (an enzyme involved in cholesterol synthesis) with this response but did not report fiber or other component levels for any of the grains. Subsequently, these researchers (Prentice et al 1982) compared a corn diet with barley and oat diets containing similar levels of β-glucan (5.2-5.8%). They reported a 22-25% reduction in total cholesterol and inhibition of key enzymes involved in cholesterol synthesis and degradation in animals consuming both the barley and oat diets (Table 4). They also found dehulled, rolled barley to be as effective as ground barley (with hulls).

Table 4. Lipid Response in Animals Consuming Barley and Oat Products Containing Similar Levels of β-glucan Soluble Fiber.

Reference/notes	Species	N / Trt[a]	No. Days	Treatments	Diet % Fiber or BG	Response %[b] TC	LDL	HDL	% Chol.[c]	Control
Jackson et al 1994	Rat	6	14	Oat bran	2.7% BG	-36	-36	-38	1.0%	Wheat bran
				Barley	2.1% BG	-32	-36	-27		
				Malted barley	0.3% BG	-30	-49	-11.8 ns		
Kahlon et al 1993	Hamster	10	21	Oat bran	4.5% BG	-13.9	-30.3	-10	0.25%	Cellulose
Whole barley – dehulled				Whole barley	3.3% BG	-10.6 ns	-13.2 ns	-4.9 ns		
GE barley - glucan				Rice bran	0.8% BG	-8.6 ns	-10.5 ns	-5.6 ns		
enhanced by milling				GE barley	3.3% BG	-1.3 ns	-2.6 ns	-4.9 ns		
/sieving				"	4.3% BG	-5.6 ns	-5.3 ns	-13		
				"	6.0% BG	-14.6%	-23.7	-15		
Prentice et al 1982	Chick	8	28	Rolled oats	5.8% BG	-25			Meat Scrap 5%	Corn
				Barley (with hulls)	5.2% BG	-22				
				Rolled barley (dehulled)	5.4% BG	-32				
Delaney et al 2003a	Hamster	10	63	Oat extract	2% BG	ns	ns	+22.1	0.15%	cellulose
					4% BG	-16.7	-26.0	ns		
Betafiber= barley extract					8% BG	-32.2	-40.6	-15.4		
				Betafiber	2% BG	ns	ns	ns		
					4% BG	-14.1	-19.5	ns		
					8% BG	-26.6	-30.4	-18.9		
Klopfenstein and Hoseney 1987	Rat	10	35	Oat bran extract	4.8% BG	-5.8 ns		+1.6 ns	5.0%	White bread
				"	8.9% BG	-15		+3.3 ns		
				Barley extract	4.8% BG	-18		+19		
				Wheat extract	4.8% BG	-12		+0.5 ns		
Oda et al 1994	Rat	8	14	Oat gum	1.3% TDF	-17				Cellulose + coconut oil
AIN-76 = cellulose, no				Barley gum	1.3% TDF	-20				
coconut oil				Guar gum	2% TDF ?	-48				
				AIN-76	2% TDF	-0.9 ns				

[a]Abbreviations: N/trt=number/treatment; TC=total cholesterol; LDL=low density lipoprotein cholesterol; HDL=high density lipoprotein cholesterol; Liver C = liver cholesterol; BG=β-glucan; SDF=soluble dietary fiber; TDF=total dietary fiber; ns=nonsignificant.
[b] All changes are statistically significant at $P<0.05$ unless noted or nonsignificant.
[c]% Chol.=% cholesterol or cholesterol source in diet.

Jackson et al (1994) reported 32-36% reduction in total and LDL-cholesterol upon feeding rats diets containing either barley or oat bran that had similar levels of β-glucan (2.1% and 2.7%, respectively). Oda et al (1994) reported a 17-20% reduction in total cholesterol when feeding rats isolated barley or oat gums both at a 1.3% TDF level. Delaney et al (2003a) showed a similar decrease in total and LDL-cholesterol in hamsters fed 2, 4 and 8% barley and oat β-glucan extracts and a significant dose response. Klopfenstein and Hoseney (1987) fed bread containing 4.8% β-glucan extracted from either barley or oat bran to rats. The barley extract reduced total cholesterol 18% but the response to the oat bran extract was not significant. However, a bread containing a higher level of the oat bran extract (8.9% β-glucan) reduced total cholesterol 15%. Kahlon et al (1993) fed hamsters a sieved barley flour and oat bran containing 4.3-4.5% β-glucan. The oat bran reduced total cholesterol 13.9% while the response to the barley was not significant. A diet containing a higher proportion of the sieved barley flour (6% β-glucan) lowered total cholesterol 14.6%.

It is apparent from these studies that small levels of β-glucan can be associated with significant decreases in total cholesterol in small animals. The Oda et al diets only had 1.3% TDF, probably most of it β-glucan, and the diets used by Jackson et al had 2.1-2.7% β-glucan. Yet cholesterol was reduced by 17-36%. For reasons not readily apparent, in small animals higher levels of β-glucan, whether barley or oat, do not appear to be any more effective than this.

The results from eight studies that compared various levels of barley and oat are presented in Table 5. Both barley and oats lowered total cholesterol in four studies though not necessarily

Table 5. Lipid Response in Animals Consuming Barley and Oat Products Compared to a Control.

Reference	Species	N / Trt[a]	No. Days	Treatments	Diet % Fiber or BG	Response %[b] TC	LDL	HDL	% Chol.[c]	Control
Newman et al 1992 Study 1	Chick	10	10	Oat bran	2.2% BG	-26	-34	+11	0.5%	Corn
P=Prowashonupana, waxy hulless				P Barley	6.1% BG	-15	-19	+2.2 ns		
W=Waxbar, waxy hulless				W Barley	2.9% BG	-32	-41	+12		
				Wheat	0.5% BG	+8	+9.1 ns	+4.4 ns		
Newman et al 1992 Study 2	Rat	10	42	Oat bran	3.3% BG	-28	-58 ns	-1.9 ns	1.0%	Cellulose
				P Barley	4.9% BG	+1.3 ns	+1.9 ns	+1.9 ns		
				W Barley	4.8% BG	-31	-59 ns	-12.8 ns		
				Wheat	0.3% BG	+3.0 ns	+26.0 ns	+17.0 ns		
Peterson and Qureshi 1997	Chick	10	23	Oat bran	5.3% BG	-29	-32	-30	Meat scrap 5%	Corn
A= Arizona Hulless, waxy (also called Azhul)				A barley	2.4% BG	-29	-37	-27		
							Liver C			
Oda et al 1993	Rat	7	9	Oat extract	1.9% SDF	-13.6 ns	-26.7		1%	cellulose
				Barley extract	2.8% SDF	-29.8 ns	-42.0			
				Wheat extract	0.6% SDF	+8.7 ns	-6.4 ns			
						Vs. oat				
Ranhotra et al 1991	Rat	10	28	Meal - oat	2.3% SDF				1%	None
				S barley	2.3% SDF	+5.5 ns				
S=Scout, hulless				E barley	3.9% SDF	-1.5 ns				
E=Ex. 85751, waxy hulless				A barley	5.1% SDF	-7.0 ns				
A=Arizona Hulless, waxy			42	Bran - oat	3.1% SDF					
				S barley	4.8% SDF	-41.6				
				E barley	5.5% SDF	-24.9				
				A barley	9.4% SDF	-55.5				
			42	Flour - oat	1.2% SDF					
				S barley	1.7% SDF	-11.6 ns				
				E barley	3.7% SDF	-26.6				
				A barley	5.1% SDF	-47.5				

Table 5. continued

Reference	Species	N / Trt[a]	No. Days	Treatments	Diet % Fiber or BG	Response %[b]			% Chol.[c]	Control
						TC	LDL	HDL		
Rieckoff et al 1999 P=Prowashonupana, waxy hulless	Hamster	10	35	Oat bran Barley P barley flakes	5.3% BG 3.2% BG 9.3% BG	-5.8 ns -4.4 ns -5.8 ns	-11 ns -11 ns -11 ns	+5.7 ns +2.8 ns -5.7 ns	0.12%	Wheat bran
Vetesi et al 2000	Geese	10	55	Oat Barley	1.0% SDF 2.3% SDF	-6.6 -10.3			Fish meal	Corn
Wang and Klopfenstein 1993 Extrusion – average of 3 screw speeds	Rat	10	42	Oat Barley Wheat Extruded oat-3 Extruded barley-3 Extruded wheat-3	1% BG 2% BG 0 BG 1% BG 2% BG 0 BG	+0.6 ns -12 +1.1 ns -25 -43 -26			1.0%	Corn

[a]Abbreviations: N/trt=number/treatment; TC=total cholesterol; LDL=low density lipoprotein cholesterol; HDL=high density lipoprotein cholesterol; Liver C = liver cholesterol; BG=β-glucan; SDF=soluble dietary fiber; TDF=total dietary fiber; ns=nonsignificant.
[b] All changes are statistically significant at $P<0.05$ unless noted or nonsignificant.
[c]% Chol.=% cholesterol or cholesterol source in diet.

proportional to the level of β-glucan consumed. In 3 of the studies the barley diet contained 1.5-2 times the amount of β-glucan as the oat diet, yet the significant reduction in cholesterol in chicks, rats and geese was similar for both diets (Newman et al 1992 and Vetesi et al 2000). In the 4th study the lipid responses in chicks were similar even though the oat diet contained twice as much β-glucan as the barley diet (Peterson and Qureshi 1997).

In the Newman et al (1992) studies two different barley varieties were tested. Of these, Prowashonupana is known to have very high levels of β-glucan, 16.9% for this sample. The diet containing this barley reduced cholesterol in the chick study but was ineffective in the rat study. Interestingly, the researchers observed a much lower extract viscosity for this variety compared to the Waxbar and oat bran. This can be explained by sprouting that would result in the degradation of β-glucan molecules but not necessarily change the β-glucan content. Sprouted grain (whether barley, wheat or oat) can be avoided by timely harvest at the production level and by specifications for sound grain at the procurement level of food manufacturing. Examples of existing raw barley specifications that include sound grain can be found in Appendix 2.

A lack of response or nonsignificant response to oat or both barley and oat was reported in 3 studies. Rieckoff et al (1999) reported that neither barley (3.2% β-glucan) or oat bran (5.3% β-glucan) lowered total or LDL-cholesterol in hamsters. However, the diets contained only 0.12% added cholesterol and baseline cholesterol levels were only 220 mg/dl. In comparison, other studies using hamsters report adding 0.25 –2% cholesterol to the diet and baseline cholesterol values of 300 mg/dl or more. Oda et al (1993) reported that diets containing barley (2.8% soluble dietary fiber, SDF) and oat (1.9% SDF) soluble fiber extracts lowered total cholesterol

29.8% and 13.6%, respectively, in rats, but these values were not significantly different from the control. However, reported reductions in liver cholesterol were significant. They also fed diets containing insoluble fiber extracts and reported no change in total or liver cholesterol. Wang and Klopfenstein (1993) investigated the effect of extrusion on soluble fiber by feeding rats both raw (whole, ground, including hulls) and extruded barley and oats. A 12% reduction in total cholesterol was reported for the raw barley diet containing 2% β-glucan while no reduction was reported for the raw oat diet containing 1% β-glucan. The extruded barley and oat diets lowered cholesterol 43 and 25%, respectively. It was suggested that extrusion processing increases the solubility of β-glucan, thus, increasing its functionality.

Finally, a rat feeding study comparing meal, bran and flour made from oats and three hulless barley varieties was reported by Ranhotra et al (1991) but without a control or baseline cholesterol. The authors assumed a typical cholesterol of 110 mg/dl in normal rats and that by feeding 1% cholesterol, this level would increase significantly. Indeed, after two weeks of diet intervention they reported that total cholesterol varied from 190 to 367 mg/dl with differences somewhat related to level of soluble fiber in the diet. By six weeks, total cholesterol in rats consuming the three oat diets and four of the barley diets had not decreased. The remaining five barley diets, all higher in soluble fiber than the corresponding oat diet, had lowered cholesterol, though a statistical analysis between the 2 and 6 week cholesterol analyses was not reported. The authors did report a statistical difference in the average total cholesterol at 6 weeks between some of the diets. For our purposes, oat was used as the control and the % response compared to oats was calculated and is presented in Table 5. The rats consuming the oat meal, bran and flour diets containing from 1.2 to 3.1% soluble dietary fiber all had similar cholesterol levels at 6 weeks. Rats consuming the three barley meals (ground whole barley) had a similar cholesterol level as rats consuming oat meal even though two of the barley meals had a higher soluble fiber content. Rats consuming the three barley brans had significantly lower (-25% to –55%) cholesterol than rats consuming oat bran, but all had a higher level of soluble fiber than the oat bran. Rats consuming barley flours with higher levels of soluble fiber than the oat flour had lower cholesterol than the oat flour consuming rats. Since a wide range of soluble fiber was fed in this study, the dose response relationship between soluble fiber and total cholesterol was also examined. A significant negative relationship was detected between SDF in the diet and total cholesterol ($r = -0.63$, $P = 0.04$) and between the SDF/TDF ratio and total cholesterol ($r = -0.85$, $P = 0.0009$). This last relationship changes very little if only the barley data is used ($r = -0.83$, $P= 0.01$).

LDL-cholesterol was analyzed in five of the above studies. In all cases, the results were parallel to the results for total cholesterol. For both barley and oats, the reduction in total cholesterol is primarily a reduction in LDL-cholesterol. HDL-cholesterol was also analyzed in six of the above studies. Three studies reported either no change or an increase in HDL-cholesterol in response to barley and oat β-glucan in the diet and three studies reported a decrease. Within each study, the HDL-cholesterol response to barley and oat β-glucan was very similar. These conflicting results do not appear to be related to dietary cholesterol level or type of animal.

The above discussions of these fourteen studies focused on comparisons of barley or oat β-glucan to a control. However, twelve of the studies reported statistical analyses (post-ANOV means test or t-tests) that reported direct comparisons between the barley and oat treatments also

(Table 6). Ten studies reported either no significant difference in total cholesterol between animals consuming barley and oats (8 out of 10), or animals consuming barley had significantly lower total cholesterol than the oat consuming animals (2). In two studies, Newman et al (1992) compared 2 barley varieties to oat bran in chicks and rats. In both studies, one of the barley varieties was equivalent to oat bran in reducing cholesterol but animals consuming the other variety had significantly higher cholesterol than those consuming the oat bran. The results for LDL and HDL cholesterol were similar to the total cholesterol data in that most of the studies reported no difference between barley and oats. These data provide a valid statistical basis for concluding that barley and oat β-glucan have similar physiological functionality in small animals.

In conclusion, the direct comparisons that have been made between barley and oats support the conclusion that they are physiologically indistinguishable in animal models. Barley containing β-glucan soluble fiber reduced total cholesterol in 12 out of 14 studies. No difference was detected between barley and oat in 10 studies that reported a statistical test between the treatments. And, when the level of β-glucan in the barley and oat treatments was low, the level of cholesterol reduction was similar in most instances. Thus, the data supports the hypothesis that barley and oat β-glucan soluble fiber are essentially equivalent on a physical, chemical and physiological basis and supports the conclusion that there is significant scientific agreement that barley β-glucan soluble fiber and the barley products that contain β-glucan soluble fiber are associated with a reduction in risk for coronary heart disease.

Table 6. Summary of Statistical Analyses Comparing Lipid Response of Barley and Oats in Small Animal Trials.

Reference	Species	Post ANOV Statistical Test	Probability Level	Barley vs. Oat Comparisons		
				Total Cholesterol	LDL Cholesterol	HDL Cholesterol
MILLED BARLEY AND OATS						
Jackson et al 1994	Rat	LSD	0.05	Nd[a]	Nd	Nd
Kahlon et al 1993	Hamster	Duncan	0.05	Nd	2 Barley Nd 2 Barley < Oat	Nd
Newman et al 1992 - Study 1 Study 2	Chick Rat	Duncan	0.05	1 Barley Nd 1 Barley > Oat 1 Barley Nd 1 Barley > Oat	1 Barley Nd 1 Barley > Oat Nd	1 Barley Nd 1 Barley < Oat Nd
Peterson and Qureshi 1997	Chick	Duncan	0.05	Nd	Nd	Nd
Prentice et al 1982	Chick	LSD	0.01	Nd	-	-
Ranhotra et al 1991	Rat	Duncan	0.05	Meal - Nd Bran – Barley < Oat Flour – 1 Barley Nd 2 Barley < Oat	- - -	Nd Barley > Oat 2 Barley Nd 1 Barley > Oat
Rieckoff et al 1999	Hamster	Bonferroni-Dunn	0.05	Nd	Nd	Nd
Wang and Klopfenstein 1993	Rat	LSD	0.05	Barley < Oat	-	-
SOLUBLE FIBER EXTRACTS FROM BARLEY AND OATS						
Delaney et al 2003a	Hamster	Student's t-test	0.05	2% - Nd 4% - Nd 8% - Nd	Nd 0at < Barley Nd	Oat > Barley Nd Nd
Klopfenstein and Hoseney 1987	Rat	Duncan	0.05	Nd	-	Barley > oat
Oda et al 1993	Rat	Dunnett's t-test	0.05	Nd	-	-

[a]Nd= no difference.

3. Controlled Comparisons with Barley in Animal Studies

Twenty-five animal trials studied the impact of consuming milled barley or isolated barley β-glucan on serum/liver cholesterol compared to a control such as corn, wheat, or cellulose. The 22 studies that reported β-glucan or dietary fiber content of the animal diets are summarized in Table 7. The majority (23) of studies found that diets containing barley or barley β-glucan significantly lowered total (8 to 72%) and/or LDL-cholesterol (20 to 80%) . Of the thirteen studies that measured HDL-cholesterol, only 3 reported a significant decrease.

Many of these animal studies were designed not only to measure a lipid response but to investigate the underlying mechanisms. Swine and chick feeding studies (Qureshi et al 1982, Qureshi et al 1983, Burger et al 1984, Qureshi et al 1984) conducted by the USDA and the U. of Wisconsin (continuation of the studies described in the previous section) consistently reported significant decreases in serum cholesterol and suppression of HMG-CoA reductase in animals of different maturities consuming various forms of barley in both short and long-term studies. Burger et al (1982) attempted to identify the location of the compounds responsible for the cholesterol lowering response by comparing whole barley to pearl barley, pearlings and a high protein barley flour (sieved pearlings). Amazingly, all the diets lowered cholesterol significantly (21 to 30%). Unfortunately neither soluble fiber nor β-glucan was measured in this study. However, the pearling fraction was high in oil indicating that it contained large quantities of germ. Later studies investigated both barley soluble fiber and barley oil for their role in lowering cholesterol.

Table 7. Lipid Response in Animals Consuming Barley Products Compared to a Control.

Reference	Species	N/trt[a]	No. Days	Treatments	Diet % Fiber or BG	Response %[b]			% Chol.[c]	Control
						TC	LDL	HDL		
MILLED BARLEY										
							Liver C			
Danielson et al 1997	Rat	10	21	S Barley shorts					0.5%	Cellulose
				30%	2.3% BG	ns	-49			
S=Shonkin				60%	4.6% BG	ns	-54			
				90%	6.9% BG	ns	-69			
Fadel et al 1987	Chick	32	21	W Barley	3.2% BG	-14	-45	+26	0.5%	Corn
W=Washonupana				+ β-glucanase		ns	-21	+31		
F=Franubet				F Barley	3.3% BG	ns	-23	+30		
				+ β-glucanase		ns	-24	+38		
German et al 1996	Hamster	8	21	Sieved barley	4.9% BG				<.04%	Cellulose
				+olive oil		ns	+16	-12		
				+fish oil		-24	-22	-18		
Kalra and Jood 2000	Rat	8	40	DM Barley	4.5% BG	-39	-61	+34	-	cellulose
DM=Dolma, hulless				DL Barley	3.4% BG	-24	ns	ns		
DL=DL-88, hulless				BM Barley	1.7% BG	ns	ns	ns		
BM=BM-331, covered										
Knuckles and Yokoyama	Hamster	11	21	S Barley – sieved	3.4% BG	ns	-57	ns	0.5%	cellulose
2000						-42	-69	ns	2%	
S=Stanuwax, waxy hulless				Cholestyramine	0.05%	-49	-60	ns	0.5%	
						-19	-20	ns	2%	
Martinez et al 1992	Chick	6	17	A barley					1%	Wheat
				+palm oil	6% BG	-72				
A=Arizona Hulless				+egg yolk	6% BG	-60				
				+corn oil	6% BG	-49				
				+butter	6% BG	-48				
				+tallow	6% BG	-55				

Table 7. continued

Reference	Species	N/trt[a]	No. Days	Treatments	Diet % Fiber or BG	Response %[b] TC	LDL	HDL	% Chol.[c]	Control
McIntosh et al 1993 BB = barley bran	Rat	10	180	BB 1 - 50% pearl BB 2 - 5% pearl	2.0% SDF 0.3% SDF	ns ns			Lard 10%	Cellulose
Newman et al 1991 W=Washonupana Wr=Waxbar B=Bangsa	Chick	24	21	W Barley + β-glucanase Wr Barley + β-glucanase B Barley + β-glucanase	3.2% BG 2.9% BG 2.6% BG	-39 -9 -36 -16 -41 -28	-63 -12 -54 -26 -63 -45	+11 ns ns ns ns ns	0.5%	Corn
Qureshi et al 1982	Swine	5	21	Barley	7.8% BG	-18			-	Corn
Qureshi et al 1984	Chick	12 12	210 84	Barley	4.7% BG 4.7% BG	-11 -23			5% Meat scrap	Corn
Ranhotra et al 1998 C=Candle, hulless	Hamster	10	28	C Barley	2.0% BG 3.9% BG 5.9% BG	-16 -20 -21	ns -24 ns	-18 -21 -21	0.25%	No fiber
							VLDL			
Shao et al 2002 HF=high fat;	hamster	9	28	Barley + HF Psyllium + HF HPMC + HF	7.7% BG 7.7% TDF 7.7% TDF	-55 -55 ns	-80 -80 ns	ns -47 ns	butter	Cellulose HF
Sundberg et al 1995 M2=sieved barley meal	Chick	24	22	M2 barley +drum dried +extruded	5% BG	ns -27 -39		ns ns -23	0.3%	+ β-glucanase
Sundberg et al 1998 G=Glacier HAG=High amylose G HHAG=Hulless HAG Fl=flour	Chick	22	24	G barley fl HAG Barley fl HHAG Barley fl	2.6% BG 2.6% BG 2.3% BG	ns -20 -28	ns -38 -57	+20 ns ns	0.5%	Corn " "

Table 7. continued

Reference	Species	N/trt[a]	No. Days	Treatments	Diet % Fiber or BG	Response %[b] TC	LDL	HDL	% Chol.[c]	Control
Sundberg et al 1998 (continued) Rd=red dog (bran)	Chick	22	24	G barley rd HAG Barley rd HHAG Barley rd	6.0% BG 6.4% BG 5.4% BG	-46 -46 -48	-69 -71 -78	ns ns +24	0.5%	Cellulose " "
Wang et al 1992 A=Azhul (Arizona)	Chick	32	8	A Barley -β-glucanase + β-glucanase	 6.9% BG 6.8% BG	 -27 -14	 -67 -48	 ns +15	0.4%	Corn
Wang et al 1997 A=Azhul (Arizona)	Hamster	15	21	A Barley -SDF -oil -(SDF + oil)	5.9% BG 0.6% BG 5.6% BG 0.5% BG	-12 ns -8 ns		ns ns ns ns	0.3%	Cellulose
SOLUBLE FIBER EXTRACTS FROM BARLEY										
Guevara 2000	Rat	9	28	Barley extract - Glucagel	7% BG	-10[d]	ns	ns		Corn
Hecker et al 1998	Rat	10	25	Barley BG extract – 55.6% BG	7.8% SDF or 1.2g/day	ns	-40	ns	1%	Cellulose
Oakenfull et al 1991	Rat	10	21	Barley BG extract	1% BG 2% BG 3% BG 4% BG		ns ns -20 -20		1%	Cellulose
Thomas et al 1990	Rat	12	75	Barley NDF	30% NDF	-26	-42		2%	No fiber
Yang and Moon 2002	Rat	21	14	Barley BG extract	2.5% BG	-Sig.	-sig.		0.5%	No fiber

[a]Abbreviations: N/trt=number/treatment; TC=total cholesterol; LDL=low density lipoprotein cholesterol; HDL=high density lipoprotein cholesterol; Liver C=liver cholesterol; VLDL= very low density lipoprotein cholesterol; BG=β-glucan; SDF=soluble dietary fiber; TDF=total dietary fiber; NDF=neutral detergent fiber; ns=nonsignificant.
[b] All changes are statistically significant at $P<0.05$ unless noted or nonsignificant.
[c]% Chol.=% cholesterol or cholesterol source in diet.
[d]$P=0.07$.

The relationship between β-glucan, viscosity and cholesterol reduction has been investigated utilizing both varietal differences and enzymes. Fadel et al (1987) fed two varieties, with the same β-glucan content but differing in their extract viscosity, with and without β-glucanase, an enzyme that reduces the molecular size of β-glucan. Only the variety with the highest extract viscosity reduced cholesterol significantly and this response was nullified by β-glucanase. The β-glucanase effect was confirmed by Newman et al (1991) and Wang et al (1992). In these studies, barley diets containing β-glucanase lowered cholesterol, but the response was significantly less than the diets without the enzyme. Newman et al did not report viscosity of the control or diets but the varietal differences in extract viscosity did not appear to be related to the level of cholesterol reduction. On the other hand, Wang et al reported a difference in extract viscosity of control and barley diets that was reflected in a significant difference in intestinal viscosity of chicks which was negatively correlated to total (-0.89, $P<0.01$) and LDL (-0.93, $P<0.01$) cholesterol. In a follow-up study, Wang et al (1997) reported that barley and defatted barley lowered cholesterol in hamsters, but barley incubated with β-glucanase and arabinoxylanase for 10 hr to remove soluble fiber had no effect on cholesterol levels. In addition, a diet containing extracted barley oil did not lower cholesterol (see later discussion). This effect of β-glucanase was exploited by Sundberg et al (1995) when they used barley diets with β-glucanase as a control. They reported that a high β-glucan barley fraction processed by drum drying and extrusion lowered cholesterol 27 to 39%, respectively compared to similar diets treated with β-glucanase.

The cholesterol response in animals to increasing levels of β-glucan have been investigated in 5 studies. A significant dose response was reported for 2 of these studies. Kalra and Jood (2000) fed rats 3 barley varieties ranging in β-glucan content from 1.7% to 4.5% and reported cholesterol reduction from 10 to 39%, respectively. Sundberg et al (1998) processed barley into flour with 2.6% β-glucan and red dog (a milling fraction containing bran) with 6% β-glucan. Both barley flour and red dog decreased cholesterol but the decrease was almost 2 times greater in chicks fed the red dog. In contrast, three studies reported decreases in cholesterol but not a significant dose response. Danielson et al (1997) fed barley shorts (a milling fraction containing large particles and bran) in increasing proportions to rats so that diets contained 2.3, 4.6, 6.9% β-glucan. Significant reductions in liver cholesterol were reported for the barley diets but the difference between levels of β-glucan was not significant. Similarly, Ranhotra et al (1998) fed hamsters increasing levels of barley so that β-glucan content of the diets ranged from 2 to 5.9%. All of the barley diets reduced cholesterol between 16 to 20%. Oakenfull et al (1991) reported that a barley β-glucan extract added to rat diets at 3 and 4% levels reduced LDL cholesterol 20% while diets containing 1 and 2% extracted β-glucan were not significantly different from the control. These data support the earlier suggestion that diets containing more than 4 to 5% β-glucan are not much more effective in lowering cholesterol in animals than diets with less than 4%.

Two studies investigated the interaction of β-glucan and type of fat consumed on the cholesterol lowering response in animals. Martinez et al (1992) reported barley diets containing 6% β-glucan reduced cholesterol from 48 to 72% depending on the fat source. The greatest reductions were reported when diets also contained palm oil or egg yolk. German et al (1996) compared barley diets for hamsters containing olive oil and fish oil. A significant reduction in cholesterol was only observed in the hamsters consuming barley and fish oil. These studies indicate a significant interaction between type of fat and levels of cholesterol reduction. And suggest that source of fat is an important aspect of these studies that always needs to be reported in order to make comparisons between studies.

Only two studies reported a nonsignificant serum total or LDL-cholesterol response to barley diets. McIntosh et al (1993) fed rats two types of barley bran, one produced by pearling 50% of the grain (BB1, 5% soluble dietary fiber) and the other produced by pearling only 5% of the grain (BB2, 1.5% soluble dietary fiber). They reported that after 90 days the BB1 reduced total cholesterol 17% compared to a wheat control, but by the end of the study (180 days), the reduction was no longer significant. Unfortunately, this study was combined with a cancer study and during the course of the investigation the same rats were subcutaneously injected with DMH (a carcinogen). This was a longer than usual study and it is not clear how the injections and subsequent tumor growth may have effected the rats. A study by Danielson et al (1997) was mentioned previously because it was designed as a dose response study. None of the barley diets lowered serum cholesterol significantly, but they did reduce liver cholesterol significantly. The barley used in this study was a milling fraction that contained 8% β-glucan, but nothing in the design or composition of the diets helps to explain the lack of changes in serum lipids.

Five studies incorporated either a barley β-glucan or neutral detergent fiber extract into rat diets. All but one reported significant decreases in either total or LDL-cholesterol. The extraction process was similar for 2 of the extracts, utilizing hot water and amylase enzymes (Oakenfull et al 1991; Thomas et al 1990), while only hot water was used for a third extract (Guevara et al 2000). The remaining two studies, Hecker et al 1998 and Yang and Moon 2002, did not describe the extraction process. The extract used by Guevara et al reduced total cholesterol but the probability of significance was only 0.07. This extract had a low molecular weight (Morgan and Ofman 1998) because endogenous β-glucanase was not inactivated. The extraction processes of Thomas et al and Oakenfull et al utilize a step that at least partially inactivates β-glucanase and while they do not report molecular weight, rats consuming these extracts responded with lower total or LDL-cholesterol. Thomas et al did not measure β-glucan or soluble fiber, but the NDF was reported to be 70% hemicellulose, probably a large amount of β-glucan. These results are consistent with the previously described studies comparing oat and barley extracts. Processes for those extracts also involved a β-glucanase inactivation step followed by hot water extraction and amylase digestion of starch.

Finally, two studies compared barley to two other cholesterol-lowering products, psyllium and cholestyramine (a resin that binds bile acids). Shao et al (2002) reported that both barley and psyllium consumed at similar levels (7.7%) in high-fat hamster diets, reduced total cholesterol 55% and VLDL cholesterol 80%. Knuckles and Yokoyama (2000) fed hamsters barley with 3.4% β-glucan and compared it to a diet containing cholestyramine (a bile acid binding resin prescribed by doctors to lower cholesterol) at two levels of added cholesterol. At the lower level of cholesterol, barley and cholestyramine reduced LDL-cholesterol to a similar extent. However at the higher cholesterol level, both total and LDL-cholesterol were significantly lower in the hamsters consuming the barley diet. Additionally, hamsters consuming the barley diets had higher levels of fecal bile acids than the control diet, but they were not as high as the cholestyramine diet. This suggests that while bile acid excretion is one mechanism of cholesterol reduction by barley, it is probably not the only one.

An increase in bile acid, sterol and fat excretion in animals consuming barley has been reported in a number of studies. Six studies reported a significant increase in fecal fat content in animals consuming barley diets: chicks (Fadel et al 1987, Martinez et al 1992, Newman et al 1991, and Wang et al 1992), rats (Hecker et al 1998) and hamsters (Wang et al 1997). Dongowski et al (2002), Thomas et al (1990) and Yang and Moon (2002) reported significantly higher levels of bile acids and fecal sterols in feces of rats consuming barley. However in studies using hamsters, Gallaher et al 1993 found that neither barley nor oat diets resulted in changes in fecal bile acids. Rieckoff et al (1999) observed a similar response in hamsters consuming barley and oat diets. In a recent study comparing barley and oat extracts in hamsters, Delaney et al (2003a) reported both diets produced similar increases in fecal cholesterol and total neutral sterols but no change in fecal bile acids. But, as mentioned previously, Knuckles and Yokoyama (2000) reported that both barley and cholestyramine increased fecal bile acids in hamsters. Recently, Kahlon and Woodruff (2003) reported that *in vitro* binding of bile acids was higher for dehulled barley and a β-glucan enriched barley than for oat bran. They suggested, that in their tests, bile acid binding appeared to be associated with insoluble fiber content. Thus, the conflicting *in vivo* results may be due to differences in the specific barley and oat products consumed and possibly insoluble fiber content. But, it is important to note that the animals physiological responses to barley and oats are extremely similar.

In conclusion, twenty-three out of twenty-five animal studies reported a significant reduction in total or LDL-cholesterol when animals consumed milled or processed barley containing β-glucan soluble fiber. Milled products included meal, bran, and flour and processed products included extruded flour and soluble fiber extracts. Three studies in which treatments containing β-glucanase enzyme did not lower cholesterol confirm the model of a direct relationship between intact barley β-glucan and cholesterol reduction. These studies provide overwhelming evidence that support the conclusion that barley β-glucan soluble fiber is associated with total and LDL-cholesterol reduction that may reduce risk of coronary heart disease.

4. Non-β-glucan Components of Barley

Two barley products, barley oil and brewer's spent grains (BSG), neither of which contains soluble fiber, have been investigated for their potential positive impact on lipid metabolism. As previously mentioned, barley oil became the focus of continuing studies conducted by the USDA and the University of Wisconsin in the 1980's. Serial extraction of a high protein barley flour (barley pearlings) produced petroleum ether and methanol soluble fractions that lowered total and LDL-cholesterol when added to chick diets (Burger et al 1984). Fractionation of these extracts and subsequent chick and swine trials identified α-tocotrienol as the active cholesterol lowering component in the lipid fraction (Qureshi et al 1986, 1987). A dose response relationship was observed in these studies. Babu et al 1992 reported total cholesterol reduction in older rats consuming 1.4% barley oil and Wang et al 1993 reported a significant total cholesterol reduction in chicks consuming 10% barley oil. On the other hand, a later study published by Wang et al (1997) reported barley oil had no effect on cholesterol in hamsters even though it contained significant levels of tocotrienols. This same study reported that diets containing both barley flour and hexane-extracted barley flour (no lipids) lowered cholesterol about the same. Peterson and Qureshi (1997) reported a similar result from their study with chicks. They also reported a significant reduction in HMG CoA reductase from both barley flour and hexane-extracted barley flour. They concluded that the level of tocotrienols in barley flour, while significant when compared to other grains, was too low to have an effect upon cholesterol. These studies suggest that while both β-glucan soluble fiber and tocotrienols may reduce cholesterol, it is the β-glucan soluble fiber that is primarily responsible for the cholesterol lowering properties of whole and milled barley products.

Brewer's spent grains (BSG) is a by-product of the brewing industry and typically contains 98% insoluble dietary fiber and is high in protein (20-30%) and lipid (6-10%) and contains 3 times more tocotrienols than the whole grain. BSG have been referred to as barley bran in the recent past probably because they contain bran and germ and very little endosperm, much like a milled bran. But BSG also contains the hulls which would not be part of a true bran (see definitions in Appendix 1). Both starch and β-glucan are broken down and utilized during the brewing process (Peterson 1994) and thus are not present at significant levels in this product.

BSG has been utilized as a dietary intervention in both human and animal studies. Two human clinical trials reported that BSG significantly lowered LDL-cholesterol. Lupton et al (1994) reported that barley bran flour and oil, both made from BSG, lowered total and LDL-cholesterol in hypercholesterolemic men and women. However, saturated fat consumption decreased significantly in these same individuals. Zhang et al (1991) conducted a 1 week crossover using a high and low fiber diet in 10 ileostomists and reported lower LDL-cholesterol in the 6 subjects that exhibited low bile acid excretion (<1000mg/24hr). Five animal studies reported a significant decrease of 5 to 22% in total cholesterol when rats (Hassona 1993; Ismail et al 1997; McIntosh et al1993), chicks (Qureshi et al 1991) and hamsters (Zhang et al1990) were fed from 10 to 30%

BSG containing 1.6 to 3% lipid in the diets. But two studies reported no change in cholesterol when animals were fed diets containing BSG (Hundemer et al1991; Zhang et al 1992).

The combined animal and human studies on barley oil and brewer's spent grains suggest that some components, possibly the tocotrienols, have the ability to effect lipid controlling enzymes and lower cholesterol. This material certainly warrants further research. However, the scientific evidence clearly shows that the β-glucan soluble fiber in whole or milled barley and in barley extracts is the predominate component responsible for the cholesterol lowering properties of barley foods.

C. β-Glucan Chemistry

One of the key scientific points presented in this petition is the physical and chemical equivalence or strong similarity of barley and oat (1→3),(1→4)-β-D-glucan soluble fiber. The scientific data that forms the technical basis for this determination is detailed in this section. The critical points are total β-glucan content, structure or composition, molecular weight, solubility and viscosity.

1. Content

The β-glucan content of barley ranges from 2 to 17% (Table 8), however the commonly grown barley varieties in North America have β-glucan levels that average about 4.3 to 5.5%. These numbers were confirmed in several independent studies. Standard malt and feed barley cultivars grown in Idaho, North Dakota, Minnesota and South Dakota (representing about 50% of US barley production) were surveyed for β-glucan content over a number of environments and years.

Table 8. Mean and range of dietary fiber and β-glucan content of barley cultivars varying in hull, starch and protein characteristics.[a]

Genotype	N[b]	Dietary Fiber (% dry wt) Total	Dietary Fiber (% dry wt) Soluble	Soluble/ Total Ratio	N (n[c])	β-glucan (% dry wt) Total	β-glucan (% dry wt) Soluble	Soluble/ Total Ratio
Standard	8	20.0 (19.0-22.4)	5.3 (3.8-6.7)	0.27 (0.20-0.32)	44 (20)	4.4 (2.0-5.9)	2.6 (1.7-3.8)	0.56 (0.42-0.79)
Hulless	19	13.0 (11.0-15.7)	4.5 (3.0-7.0)	0.35 (0.23-0.45)	55 (12)	5.1 (4.1-6.4)	3.0 (2.2-3.7)	0.61 (0.47-0.72)
Waxy starch, hulled	3	20.7 (20.0-21.0)	6.7 (6.4-7.2)	0.32 (0.31-0.34)	10 (5)	5.8 (4.7-7.3)	3.3 (2.7-4.2)	0.58 (0.50-0.69)
Waxy starch, hulless	20	15.8 (13.1-20.1)	7.0 (5.2-10.2)	0.44 (0.32-0.55)	35 (7)	7.0 (5.1-11.3)	4.0 (3.2-4.8)	0.67 (0.55-0.73)
High protein, hulless		Na[d]	na	na	3 (2)	6.9 (5.9-8.0)	3.8 (3.5-4.1)	0.60 (0.51-0.69)
Waxy starch, high protein, hulless	2	33.7 (33.4-34.0)	18.9 (18.1-19.6)	0.56 (0.54-0.58)	4 (1)	16.6 (14.7-17.5)	6.6	0.40
High amylose starch, hulless	2	17.6 (17.2-17.9)	7.2 (6.8-7.5)	0.40 (0.40-0.42)	5 (2)	7.2 (6.0-7.9)	2.5 (2.1-2.9)	0.36 (0.35-0.37)

[a]Taken from Fastnaught CE (2001) Barley fiber. In, eds. S. Cho and M. Dreher, Handbook of Dietary Fiber. Marcel Dekker, NY, NY. pp. 519-542.
[b]N=number of cultivars/samples averaged to calculate mean Total and Soluble Dietary Fiber and Total β-glucan.
[c]n= number of cultivars/samples averaged to calculate mean soluble β-glucan.
[d]na = not available.

Twenty-seven widely adapted cultivars grown in Aberdeen, Idaho from 1996 to 2000 had a mean β-glucan content ranging from 4.1 to 5.5% (Obert 2002). Seven adapted cultivars grown in 8 North Dakota environments from 1988 to 1990 had a mean β-glucan content ranging from 4.3 to 4.7% (Horsley et al 1992). The Regional Barley Crop Quality Report (Schwarz et al 1990-1992; Schwarz et al 1994-1995; Barr et al 1997-1999) shows that the average β-glucan content of composite barley samples from ND, MN, and SD ranged from 3.9 to 4.63 over an 11 year period. These values compare quite favorably to the β-glucan content of oats. Webster (2002) reported that U.S. oats had an average β-glucan content of 4.2% with a range of 2.2 to 6.6%. While the average β-glucan contents of the commonly grown cultivars of barley and oats are quite similar, some specialty varieties of barley have extremely high β-glucan contents. This is especially true of the waxy (high amylopectin starch) hulless types which exhibited β-glucan contents ranging from 5.1 to 17% (see Table 8). Thus, one can readily conclude that the β-glucan content of the commonly grown commercial barley cultivars is equivalent or superior to that of the current commercial oat cultivars. Additionally, hulless barley has significantly greater β-glucan contents than oats and in some cases the β-glucan content is equivalent or superior to oat bran.

2. Distribution within the grain

β-glucan is one of the primary components of the cell walls of both barley and oats. However, there are some subtle differences in regard to the anatomical distribution of β-glucan especially in the traditionally grown varieties of the two cereals. The (1→3),(1→4)-linked β-D-glucans can be identified visually in both barley and oats using Calcofluor White M2R New stain (Wood et al, 1983). In stained cross sections of both barley and oats (Figure 2), the cell walls appear blue as a result of a specific interaction between Calcofluor and the (1→3)(1→4)-linked β-D-glucan

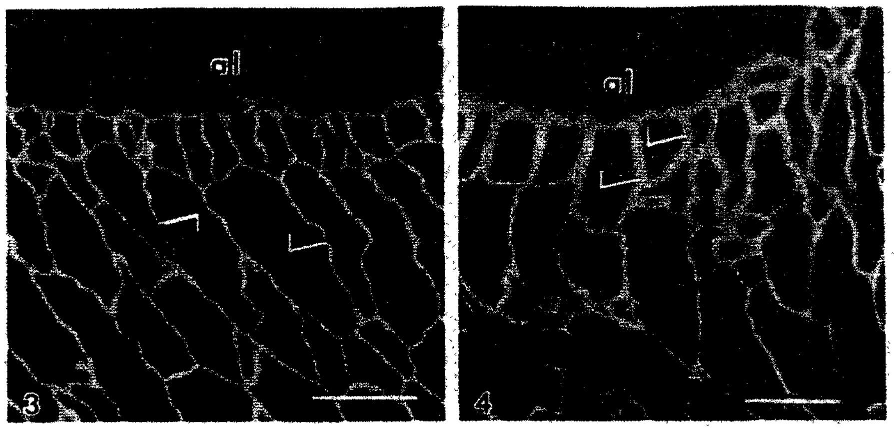

Figure 2. Sections of barley (3) and oat (4) stained with Calcofluor showing fluorescence in the cell walls. Bar = 120 μm. *Taken from,* Fulcher and Wood 1983.

(Fulcher and Wood, 1983). These images show a similar distribution of β-glucan between barley and oats. However, note Figure2-4 shows that the oat aleurone cell walls (outer tissue layer of the grain) are thicker than the same cell walls in barley. This indicates a slightly higher β-glucan content in the outer tissue of oats. Miller and Fulcher (1994) compared five oat and five barley cultivars for β-glucan distribution in the grain. The cultivars ranged in β-glucan content from2.8% to 11%. Microspectrofluorometric scans of cross sections of the central region of individual grains are shown in Fig. 3. As previously shown, the oat cultivars, which range in β-glucan from 3.7% to 5.1%, typically have a higher concentration of β-glucan located in the aleurone. The barley cultivars ranging in β-glucan from 2.8% to 11% have β-glucan distributed evenly throughout the grain with much higher concentrations in the endosperm than found in oats. Note, the standard oat varieties have very thin endosperm cell walls which is indicative of a lower β-glucan content of the endosperm tissue. The Marion oats with 6.4% β-glucan is more similar to the barley with β-glucan distributed equally across the endosperm. Oscarsson et al

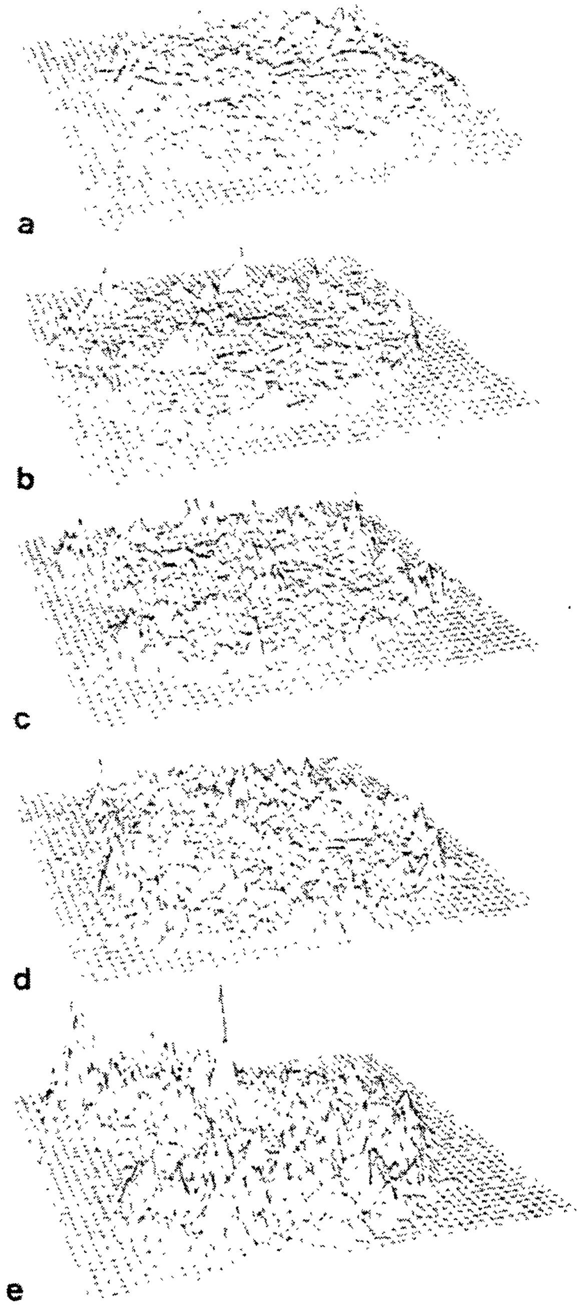

Fig. 4. Distribution of β-glucan (%, dwb) in the central region of five oat cultivars as detected by microspectrofluorometric scanning of the relative fluorescence intensity of bound Calcofluor. **a,** Donald, 3.7%; **b,** OA516-2, 4.0%; **c,** Tibor, 4.6%; **d,** Woodstock, 5.1%; **e,** Marion, 6.4%.

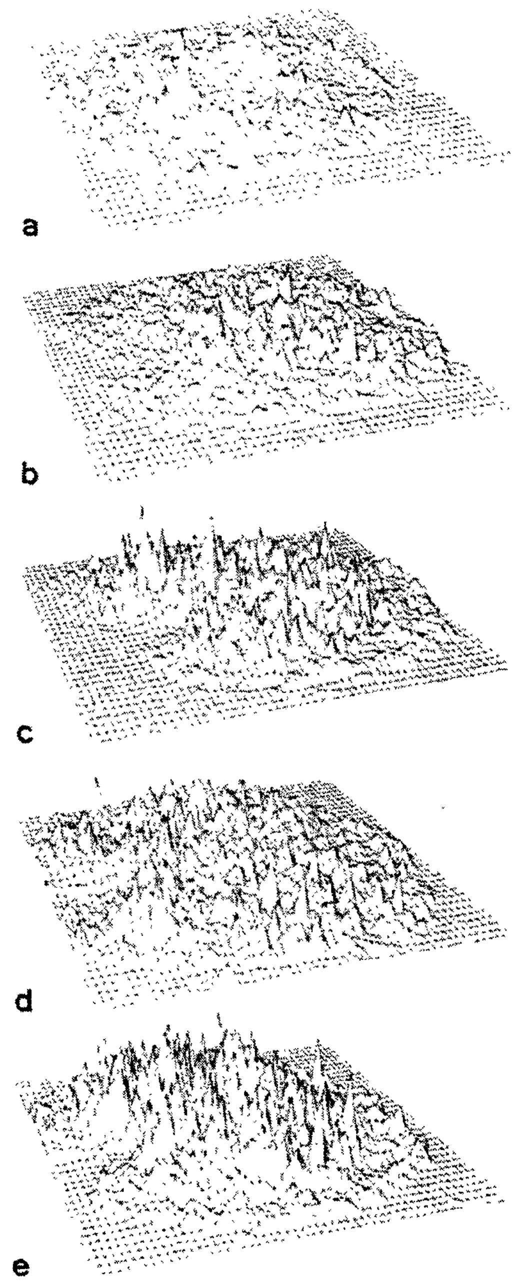

Fig. 5. Distribution of β-glucan (%, dwb) in the central region of five barley cultivars as detected by microspectrofluorometric scanning of the relative fluorescence intensity of bound Calcofluor. **a,** M-737, 2.8%; **b,** Chalky Glenn, 3.2%; **c,** Leger, 5.7%; **d,** Minerva, 6.0%; **e,** Arizona, 11.0%.

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Figure 3. Microspectrofluorometric scans of cross sections of the central region of individual grains in 5 oat (left) and 5 barley (right) cultivars. *Taken from*, Miller and Fulcher 1994.

(1997) used Calcofluor to examine the microstructure of barley cultivars differing in amylose content. Fig. 4 provides a graphic demonstration of the variation in barley cell wall thickness and cell size that results in the varying levels of β-glucan in these genotypes.

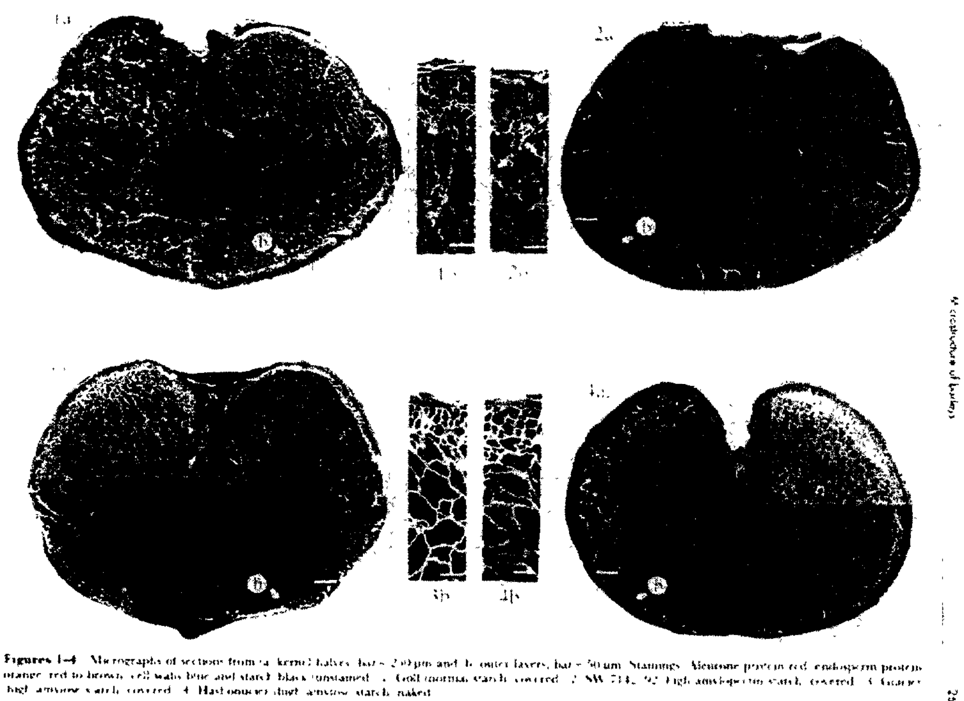

Figure 4. Cross sections of four barley cultivars stained with Calcofluor showing blue fluorescent cell walls. β-glucan content is 4.8% for Golf (1a), 5.8% for SW 7142-92 (2a), 5.6% for High Amylose Glacier (3a), and 6% for Hashonucier (4a). *Taken from*, Oscarsson et al 1997.

3. Structure

Barley and oat β-glucan are very similar in structure. In both cases glucose molecules are linked by two types of β-linkages, about 30% β-(1→3) and 70% β-(1→4). Numerous structural studies have shown that most of the β-(1→4) linkages occur in groups of two (cellotriosyl or DP3) or three (cellotetraosyl or DP4) connected by a single β-(1→3) linkage (Edney et al 1991). Research on β-glucan structure has focused on characterization of molecular weight and on the products of lichenase digestion which have been likened to a structural fingerprint (Wood et al 1994). Lichenase digestion of barley and oat β-glucan produces oligosaccharides with a degree of polymerization (DP) ranging from 3 to 15. Approximately 92% (by weight) of the oligosaccharides are DP3 or DP4. In studies that included both barley and oats, the molar ratio of DP3/DP4 is reported to range from 2.4 to 3.4 in barley and 2.0 to 2.7 in oat (Wood et al 1991, Edney et al 1991, Wood et al 1994, Johansson et al 2001). Jiang and Vasanthan (2000) reported that water soluble β-glucan from 10 barley cultivars (2 pearled) had a lower molar ratio ranging from 2.1 to 2.8. In contrast, the DP3/DP4 ratio of wheat β-glucan is 4.5 (Cui et al 2000) and lichenin is 24.5 (Wood et al 1994). It has been suggested that a higher proportion of β-(1-3) linked cellotriosyl units (higher molar ratio) could lead to a greater structural regularity resulting in decreased solubility (Wood et al 2003). However, there is no evidence that the small difference between barley and oats molar ratios results in an *in vivo* difference in β-glucan solubility or serum lipid response in small animals.

4. Molecular weight

The peak molecular weight of barley β-glucan has been reported to vary from 0.2×10^6 to 2.66×10^6 (Table 9). While oat β-glucan is reported to vary from 1.27×10^6 to 3.03×10^6, most oat cultivars have a β-glucan molecular weight greater than 2 x 10^6. However, when reviewing the data, several factors must be taken into consideration. Firstly, solvent type and extraction temperature have a significant effect on the molecular weight of extracted beta-glucan (Edney et al 1991). Strong acid or base is often used to "completely" extract total β-glucan from barley and oats. Some studies suggest that β-glucans extracted with water tend to have lower molecular weight than those extracted with alkali. Secondly, the cultivar genetics and growing environments also affect β-glucan molecular weight (Knuckles et al 1997). And finally, enzyme activity is a critical factor that must be considered when reviewing β-glucan molecular weight data. Both oats and barley may have significant quantities of active β-glucanase. Hot ethanol or NaOH treatments prior to extraction have been recommended (Knuckles and Chiu 1999, Rimsten et al 2003). If researchers do not take proper precautions, the reported β-glucan molecular weights may be significantly lower than actual values. This factor also impacts upon viscosity as is pointed out in the discussion in that section.

Only a few studies have reported molecular weight data for both barley and oats (Table 9). The published data suggests that barley β-glucan, on the average, may have a slightly lower molecular weight than oat β-glucan. In general, there is a significant overlap in the molecular weights of barley and oat β-glucan which suggests that the difference if any is minimal. Note cereal β-glucans are polydisperse and quoted values usually refer to a chromatographic peak or a distribution average such as M_w or M_n. These give different numbers, thus care must be taken when comparing scientific results.

Table 9. Weight Average and Peak Molecular Weight of β-glucan from Barley and Oats.

Reference	Solvent	Barley	Oat	Notes
Molecular Weight (weight average g/mol x 10^6)				
Copikova et al 2000	Water, 100^{0}C	1.2 - 1.6		24 barley genotypes
Girhammar and Nair 1992	Water	0.67	0.45	1 barley, 1 oat cultivar
Johansson et al 2000	Water, 96^{0}C /enzyme		1.1 - 1.6	commercial oat bran
Knuckles et al 1997	Water, 23^{0}C	0.72 - 2.34		1 normal, 3 waxy hulless barley cultivars
	NaOH-$NaBH_4$	2.92 - 3.30		2 waxy hulless barley cultivars
Knuckles and Chui 1999	Water, 23^{0}C	0.27 - 0.66		1 normal, 2 waxy hulless barley cultivars
	NaOH	0.8 - 1.2		"
	NaOH pre- + NaOH	1.32 - 1.87		"
Rimsten et al 2003	Water, 100^{0}C	1.64	2.25	1 barley, 1 oat cultivar
	NaOH	173	185	"
	Na_2CO_3	162	181	"
Skendi et al 2003	Water, 47^{0}C		0.27 – 0.85	2 oat cultivars
Peak Molecular Weight (g/mol x 10^6)				
Beer et al 1997	Water, 90^{0}C /enzyme	1.32 – 1.69	2.09 – 2.51	8 barley, 6 oat cultivars
	NaOH	1.26	1.27	1 normal barley, 1 oat cultivar
Izydorczyk et al 1998a	Water, 40^{0}C & 65^{0}C	0.2 - 0.3		1 barley cultivar, sequential extracts
Izydorczyk et al 1998b	Water/ NaOH	0.4 – 1.6		"
Rooney Duke 1996	Water, 65^{0}C	0.58 – 1.31		Sequential extracts, 24 barley cultivars
	NaOH	1.02 – 1.6		"
Schwarz and Lee 1995	Na_2CO_3, pH 10	3.2		1 waxy hulless barley cultivar
Wood et al 1991	Na_2CO_3, pH 10	1.70 – 2.66	2.89 – 3.03	4 normal barley, 4 oat cultivars

5. Solubility and Viscosity

The viscosity of barley and oat slurries or extracts is a function of the solubility of β-glucan in a particular solvent but that solubility will vary with temperature and time. A standard method to compare β-glucan solubility developed by Aman and Graham (1987) has been used in a number of studies. First, soluble β-glucan is extracted with water for 2 hours at 38°C. Next, the β-glucan content of the residue is measured enzymatically and subtracted from total β-glucan content. The result is reported as soluble β-glucan. They reported that oats had an average of 80% soluble β-glucan (65-90%, 121 cultivars) and barley had an average of 54% (38-69%, 64 cultivars). More recently, Lee et al (1997) reported that 10 oat cultivars grown in North Dakota averaged 82% soluble β-glucan (79.5-83.9%) and 9 barley cultivars averaged 65% (59-71%).

While oat β-glucan solubility was higher than barley in the previous studies, Doehlert et al (1997) reported the correlation between viscosity and β-glucan content is higher for barley than oat, r=0.98 and 0.84, respectively. Also, viscosity of water slurries (held for 3 hr at 25°C) were higher for whole barley than whole oats (Figure 5). The viscosity of slurries made from groats derived from the whole oats was more similar to the whole barley. They also reported that steaming samples prior to grinding was an effective means of reducing β-glucanase activity in both oats and barley. Svihus et al 2000 reported that 20 cultivars each of barley and oat grown in Norway had a similar mean and range for water extract viscosity (18.6, 6.6-33.4; 17.7, 9.0-31.5; respectively).

Few studies have related *in vitro* and *in vivo* solubility. Johansen et al (1997) reported *in vitro* β-glucan solubility of intact oat bran was 17% in water (1 hr, 38°C) but increased to 73% during

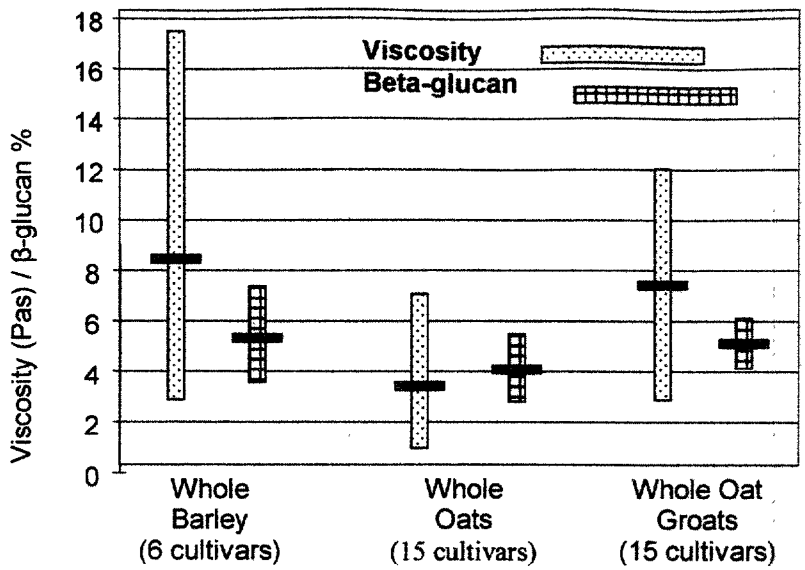

Figure 5. Range (vertical bars) and mean (horizontal bars) of water slurry viscosity and β-glucan content of barley and oats grown in North Dakota (taken from Doehlert et al 1997).

fiber analysis (check on conditions). *In vivo* β-glucan solubility of the same oat bran was as high as 55% in the pig small intestine 3 hr after consumption. But, in this study, *in vivo* viscosity was never as high as *in vitro* viscosity. Robertson et al (1997) reported similar solubility levels for barley β-glucan. Water solubility (38°C) of the β-glucan in a barley flapjack was 28% but was increased to 50-80% upon treatment with various proteases (similar to what would be used in fiber analysis). β-glucan recovered from ileal effluent was 60% soluble. Viscosity of the effluent was considered low but was only compared to a commercial mucin preparation, not a ileal effluent without β-glucan.

It is generally accepted that viscosity of a purified extract is a function of molecular weight and concentration (Wood et al 2000), but it is rare that viscosity determinations are made on purified β-glucan. The samples vary in their form and source, sample preparation is not standardized and methods to measure viscosity vary, making interpretation and comparisons between studies difficult.

Six of the previously mentioned small animal studies reported *in vitro* viscosity along with the serum lipid data. Two of these studies reported *in vivo* intestinal viscosity as well. As discussed previously, Wang et al (1992) reported significant negative correlations between viscosity of small intestine digesta of chicks and plasma total (r=-0.89) and LDL cholesterol (r=-0.93) and a significant positive correlation with fecal lipid content (r=0.91). The barley diet had a significantly higher *in vitro* and *in vivo* viscosity compared to corn. Danielson et al (1997) reported that intestinal digesta viscosity in rats increased proportionately with % β-glucan and *in vitro* viscosity of barley diets. Unfortunately, no change in serum lipids was detected but a significant decrease in liver cholesterol was negatively proportional to the increasing intestinal viscosity.

Significant increases in fecal fat that appear to be related to *in vitro* diet viscosity was also reported by Fadel et al (1987) and Newman et al (1991). Fadel et al fed chicks barley diets containing 3.2% β-glucan from two different barley varieties, Washonupana and Franubet. Washonupana had a higher alkaline extract viscosity than Franubet which carries a mutated gene that affects starch structure and lowers extract viscosity. Significantly lower total serum cholesterol and higher fecal fat content was observed only in chicks consuming the diet containing Washonupana. Newman et al fed chicks three different barley varieties with β-glucan content ranging from 2.6% to 3.2% and acid extract viscosity from 1.9 to 6.7 cP. While all of the diets lowered cholesterol compared to the corn control, only the diet with the highest viscosity increased fecal fat significantly. Unfortunately, viscosity of the control diet was not determined.

In a subsequent study, Newman et al (1992) compared diets containing two barley varieties, oat bran and wheat to a corn or cellulose control in both chicks and rats. Oat bran and Waxbar barley had an almost identical (7.3 cP) *in vitro* viscosity that was higher than the second barley (2.5 cP) and wheat (1.4 cP). Chicks and rats consuming the oat bran and Waxbar diets had significantly lower cholesterol than chicks consuming the control or second barley or wheat diet.

Finally, Kahlon et al (1993) measured viscosity (phosphate buffer, pH 6.5, 37°C, over 3 hrs) of diets containing GEB (barley that is β-glucan enriched by grinding and sieving) and oat bran. The three GEB diets containing 6.0, 4.3 and 3.3 % β-glucan had a higher viscosity than the diet with oat bran (4.5% β-glucan) during the first 60 minutes of the testing (Figure 6). But, the viscosity of the barley based diets decreased over time suggesting the presence of active beta-glucanase. This enzyme would be inactivated in the processing oats receive prior to oat bran production. Thus, the viscosity of the oat samples increased over time as a result of increasing β-glucan solubility. Proper handling of the barley prior to testing would have eliminated this problem. Of these samples, only the oat bran and the GEB with 6% β-glucan significantly reduced total and LDL-cholesterol.

Molecular weight, structure, solubility and concentration all have an effect upon the viscosity of β-glucans from barley and oats which in turn may impact the cholesterol lowering functionality of these soluble fibers. The studies of Sundberg et al (1996) provide an interesting comparison between barley and oat β-glucan functionality. These researchers utilized an ileostomist technique to compare the digestion of breads prepared from a fiber rich barley fraction and oat bran. They evaluated β-glucan degradation in the small intestine by measuring the molecular

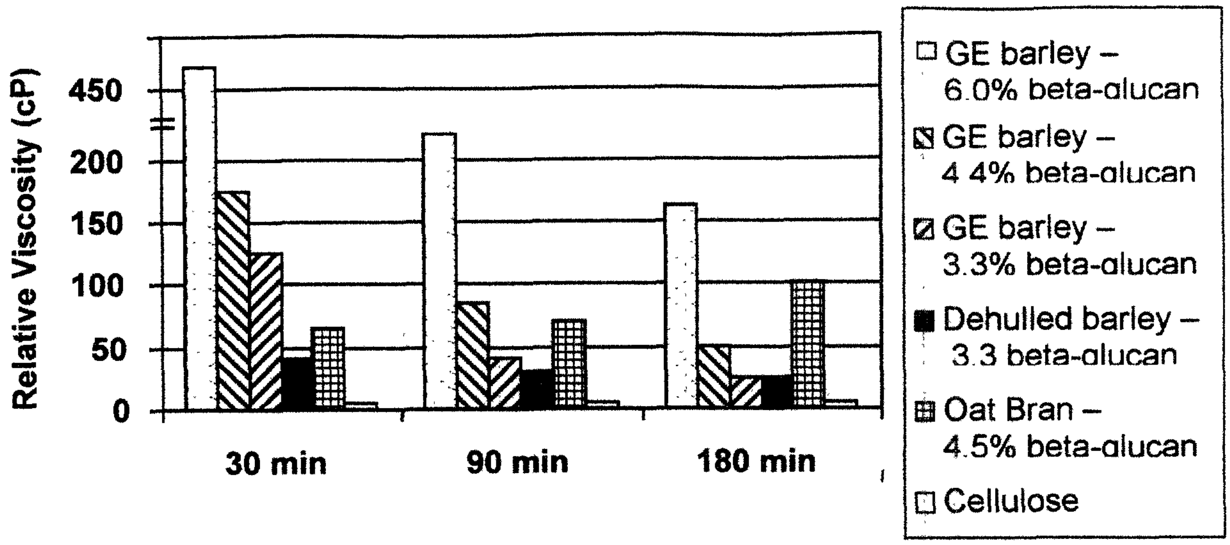

Figure 6. Viscosity of hamster diets containing glucan enriched (GE) barley, dehulled barley, oat bran or cellulose (taken from Kahlon et al 1993).

weight of the β-glucan in the ileostomy effluent. The barley fraction and the oat bran had a similar *in vitro* viscosity (measured on 1 g) over a 60 minute time period even though the barley bran contained 7% β-glucan and the oat bran had 9% β-glucan. But, the oat bran β-glucan had a higher peak molecular weight than the barley β-glucan. Interestingly, the barley developed peak viscosity much faster than oat bran which suggests that this barley β-glucan was solubilized in the intestine much quicker than oat β-glucan. In addition, the molecular weight of the oat bran β-glucan was reduced 73% in the ileostomy effluent while the molecular weight of the barley β-glucan actually increased. Unfortunately, the researchers did not measure the viscosity of the effluent.

Finally, viscosity is considered by the FDA to be one of the most important characteristics of β-glucan soluble fiber. The agency (FDA 2002) stated, "Although we do not recognize a standard method for measuring soluble viscosity applicable to a range of conditions, we do accept that soluble fiber viscosity is a major physiochemical property responsible for physiological effects of consuming soluble fiber, e.g., lowering blood lipids…". While there appear to be some differences in solubility, overall, barley and oat β-glucan produce similar levels of *in vitro* and *in vivo* viscosity in the experimental systems described in the literature. In fact, barley and oat foods with similar viscosity produced equivalent reductions in total cholesterol. These data corroborate the conclusion that barley and oat β-glucan soluble fiber are physiologically indistinguishable in animal models.

D. Bioequivalence of Barley and Oat β-glucan Soluble Fiber

Overall, the scientific evidence presented clearly demonstrates the bioequivalence of barley β-glucan soluble fiber to oat β-glucan soluble fiber. In summary:

1. Previous submissions to the FDA have confirmed that (1→3),(1→4)-β-D-glucan soluble fiber is the primary component responsible for the cholesterol lowering effect of rolled oats, oat bran, whole oat flour and oatrim (Beta Trim™). Barley, dehulled, hulless or pearled and derived products, contain as much or more (1→3),(1→4)-β-D-glucan soluble fiber as oats.
2. A controlled human clinical trial has shown that barley products consumed to provide 3g and 6g of β-glucan soluble fiber daily significantly lowered total and LDL cholesterol more than 5%. Behall et al (2004) reported that a diet including a combination of pearled barley, flaked barley and sieved barley flour providing 6 g/day β-glucan soluble fiber reduced total cholesterol 16.6% and increased HDL cholesterol 7.3%. While not conclusive, the data also indicates that barley products providing 3g/day β-glucan soluble fiber lowered cholesterol

10.8%. These reductions are equivalent or greater than the reductions observed for oat β-glucan soluble fiber.

3. Seven additional human clinical trials are limited by a lack of fiber data or design problems. Still, the 44g of pearl barley consumed in the Ikegami et al (1996) study significantly reduced total and LDL-cholesterol. In comparison, 40g of oat bran or 60g of oatmeal were initially considered the minimum levels for consumption to provide 3g of oat β-glucan soluble fiber. Additionally, consumption of equal weights of barley and oatmeal flour in the Newman et al (1989b) study resulted in the same percent reduction in total cholesterol. These data support the conclusion that a level of barley β-glucan soluble fiber close to 3g/day may reduce risk of CHD.
4. Thirty-five out of thirty-nine animal nutritional studies reported that barley β-glucan soluble fiber significantly lowered total and/or LDL cholesterol from 8 to 80%. Barley products tested include meal, flour, bran, sieved flour (β-glucan enriched flour) and extracts.
5. Barley and oats were directly compared in fourteen animal studies. Twelve of these studies reported that barley lowered total and LDL cholesterol greater than or the same as oats.
6. The $(1\rightarrow3),(1\rightarrow4)$-β-D-glucan soluble fiber is a major component of both barley and oat cell walls. The primary difference between the two grains is β-glucan distribution in the kernel. Barley endosperm cell walls contain more β-glucan than oats and oat aleurone cell walls contain more β-glucan than barley.
7. Few direct comparisons have been made between barley and oat for *in vitro* or *in vivo* viscosity. The limited data suggest that barley and oat β-glucan have similar intestinal solubility and *in vitro* slurry viscosity. Limited studies suggest a negative relationship

between *in vitro* slurry viscosity of barley diets and serum total and LDL-cholesterol reduction.

E. Other Potential Health Effects

In addition to their impact on total and LDL cholesterol, soluble fiber and dietary fiber have been shown to a exert a positive impact on blood glucose control, insulin response, satiety and obesity, and blood pressure control. All represent serious health risk factors. Additionally, recent evidence has shown that consumption of whole grain products reduced the incidence for a variety of cancers. Thus consumption of fiber containing cereal products has a significant impact on both the quality of life and the economic costs of health care for the U.S. population.

1. Beneficial Effects on Glucose Tolerance and Insulin Resistance

The incidence rate of type 2 diabetes mellitus (DM) is rising rapidly in the U.S. (Mokdad et al, 2000). In 1998, 600,000 new cases were diagnosed in the U.S. (Harris et al, 1998). Overall, this disease currently affects about 16 million people in our country. Worldwide 135 million people were estimated to have diabetes, this number is expected to increase to 300 million by 2025 (King et al, 1998). Obesity, insulin resistance and compensatory hyperinsulinemia are all key factors in the etiology of type 2 DM (Eriksson et al, 1989; Kahn, 1994)

A significant body of research has shown that grains, grain based products and soluble fibers (including β-glucan) improve glucose tolerance and reduce insulin resistance. Insulin resistance plays a central role in the pathophysiology of type 2 DM. Insulin resistance occurs when much higher levels of insulin are required to maintain normal plasma glucose homeostasis (O'Doherty et al 1997). Furthermore, diabetes is a major risk factor for CHD. Recently, the report from the *NCEP Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults* (2002) concluded that diabetes is a major risk factor for CHD and elevated it above other risk factors to being equivalent to having established CHD. Thus, dietary measures for controlling diabetes play an important role in reducing the risk of CHD.

The physiological impact of individual foods on plasma glucose and insulin response varies depending upon the type and concentration of carbohydrate present in the product. A classification system, Glycemic Index (GI), was developed to evaluate the impact of various food products upon postprandial plasma glucose. The GI is the ratio of the incremental blood glucose under the curve of a test food to the incremental blood glucose under the curve of wheat bread x 100. Typically, foods with a low degree of starch gelatinization (more compact granules) such as spaghetti, and whole grains that contain high levels of viscose soluble fiber, such as barley, oats and rye have a slower rate of digestion and lower GI values (Liu, 2002). Table 10 compares the GI of the common cereal grains. Note pearl barley has one of the lowest GI's and rolled barley is equivalent to quick oatmeal.

GI is a function of structure, starch type, fiber content and the interaction of these characteristics (Granfeldt et al 1994). Livesey et al (1995) found that ileostomists eating finely ground barley had 2% undigested starch compared to 17% when they consumed barley flakes. Light microscopy of the ileal effluent showed starch granules surrounded by intact cell walls. Liljeberg and Bjorck (1994) reported breads made with ground wholemeal barley were similar to white bread (GI=100) while breads containing 80% intact barley kernels were significantly lower

Table 10. Glycemic Index (GI) of Selected Grains and Grain Products.[a]

Whole Grain	GI	Processed Grain	GI
Barley, including pearled	25	Rolled barley	66
Corn, sweet kernel	55	Corn flakes	84
Oatmeal, Old Fashioned	49	Oatmeal, Quick	66
Rice, brown	55	Krispy, rice	88
Rice, sweet, low amylose	88	Rice, high amylose	59
Rye, whole kernel	34	Rye flour bread	65
Wheat, whole kernel	41	Puffed wheat	74
Bulgur, wheat	48	Wheat flakes	75

[a] From Behall and Hallfrisch, (2002)

(GI=33). Granfeldt et al (1994) reported GI was lowered to 66 when ground wholemeal barley flour was boiled and eaten as a porridge and suggested that boiling released the soluble fiber more effectively than baking. More recently, Liljeberg et al (1996) reported a lower GI (71 to 77) for both porridge and bread made from a barley flour containing 18% β-glucan. Cavallero et al (2002) reported a GI of 69 for bread containing 6.7% β-glucan extracted from barley with water. Yokoyama et al (1997) reported that pasta containing 7.7% β-glucan, made from a β-glucan enriched barley flour, produced a 63% lower peak glucose and 53% lower insulin response in subjects compared to the control durum pasta. In a longer study involving 11 non-insulin dependent diabetics eating barley bread products which provided 5.2g/d β-glucan, Pick et al (1998) reported a lower glycemic response, but in contrast to studies with healthy test subjects, a higher insulin response. This resulted in four subjects reducing their dosage of hypoglycemics. Wursch and Pi-Sunyer (1997) reported that foods containing 10% viscous β-glucan soluble fiber from oats and barley can reduce glucose and insulin response in the blood stream by 50% compared to white bread.

A number of studies suggest that the more immediate effect of fiber on glucose response requires it to be consumed at every meal. These studies reporting the effects of oat ß-glucan on glycemic index and glucose response have included levels of ß-glucan ranging from 0.8g to 14.5g. Hallfrisch et al (1995) found no significant difference in glucose and insulin reduction when subjects consumed daily either 1g or 7.6g of an extracted oat ß-glucan. Tappy et al (1996) varied ß-glucan content from 4g to 8.4g in cereals fed to subjects at breakfast. All three levels lowered insulin response about 35%. Glucose response was lowered 35% by the 4g level and 60% by the 6 and 8.4g level. Wood et al (2000) reported similar decreases in glucose response when subjects consumed 3.6 to 7.2 g of oat ß-glucan. These decreases were only slightly higher than decreases observed in the subjects consuming 1.8g. Liljeberg et al (1996) reported a glycemic index of 72 and 58 for meals containing 8g and 14g of barley soluble fiber. Recently, Hallfrisch et al (2003b) conducted a direct comparison of barley, oats and ß-glucan extracts from barley and oats (Nu-trim X) on glucose and insulin responses in non-diabetic men and women. Glucose responses to the barley and oats and ß-glucan extracts from both grains, as measured by the areas under the curve, were significantly lower than the glucose control ($P<0.0001$) Insulin responses for the barley extract were the lowest and were significantly lower than the glucose control. Both barley and oats extracts retained the beneficial effects of the grains from which they were extracted. In this test, high soluble fiber barley was more effective than standard oats. Wood et al (2000) related glucose and insulin response to concentration and molecular weight of ß-glucans in a drink consumed by subjects. They reported that viscosity was positively correlated

(R^2=0.97) to molecular weight x concentration which was inversely related to glucose and insulin response.

In summary, there is considerable evidence showing that consumption of foods with a low glycemic index may provide considerable health benefits especially for diabetic subjects (McLaren, 2000). The accumulating data indicate that low glycemic-index (GI) foods containing soluble fiber (ß-glucans) not only prevent certain metabolic ramifications of insulin resistance, but also reduce insulin resistance (Reaven, 1993). Furthermore, the scientific data presented in this document clearly demonstrates that ß-glucan soluble fiber from both barley and oats positively impacts the glucose and insulin response in individuals consuming these cereal products. Since over 16 million Americans are diabetics, with 90% having type 2 DM, this has extremely important ramifications in regards to the health and welfare of the U.S. population. Concurrent with the growing prevalence of obesity, the incidence of diabetes has increased by 33% from 1990 to 1998. Additionally, as the percentage of older Americans increases (retirement of baby boomers), we can expect to see substantial increases in the number of individuals experiencing problems with diabetes and insulin response. Thus, this issue has significant economic and "quality of life" implications. Increased consumption of barley (or oat based) products containing ß-glucan soluble fiber in conjunction with diet moderation as outlined in the USDA/USDHHS guidelines will help address this health problem and in the process may reduce the risk of CHD.

2. Beneficial Blood Pressure Effects

Hypertension is another major risk factor for CHD (Krauss et al, 2000). This disorder affects over 50 million Americans and is one of the most common cardiovascular disorders in the U.S. (Burt et al 1995; Sutherland et al 1994). Pins and Keenan (1999) estimated that a population wide reduction in the U.S. of 5mm Hg in diastolic blood pressure would prevent approximately 100,000 strokes per year. Two recent reports from the *Dietary Approaches to Stop Hypertension(DASH)* Study Group (Appel et al, 1997: Sacks et al, 2001) indicate that intake of whole grains –along with fruits and vegetables- have a significant effect in decreasing systolic and diastolic blood pressure. These studies support the extensive studies of Anderson et al (1994) detailing the favorable effects of dietary fiber on blood pressure. Furthermore, epidemiological studies have shown that increased consumption of dietary fiber is associated with lower levels of systolic and diastolic blood pressure (Joffres et al, 1987; Witteman et al, 1989; Ascherio et al, 1996).

Reduced blood pressure has been associated with soluble fiber from oat based products. He et al (1995) demonstrated, in a study of the relationship between dietary fiber from cereal sources and blood pressure, that oat fiber was significantly and inversely associated with systolic and diastolic blood pressure. This relationship was attributed to oat soluble fiber and not to total dietary fiber intake. Pins and Keenan (1999) demonstrated that the addition of oat soluble fiber to the diets of hypertensive subjects produced significant reductions in both systolic and diastolic blood pressure. Although there is a paucity of information available on the impact of barley soluble fiber (β-glucan), the existing evidence is consistent with the oat data. Hallfrisch et al (2002, 2003a) reported that barley foods (providing 3 or 6g β-glucan/day) added to a Step 1 diet lowered diastolic and mean arterial blood pressure 5% after 5 weeks of consumption by moderately hypercholesterolemic men.

The existing body of scientific evidence suggests that dietary fiber, in particular soluble dietary fiber such as β-glucan, may have a positive impact upon blood pressure. Katakam et al (1998) and Pins and Keenan (1999) postulated that the positive effects on blood pressure may be related to it's influence on insulin resistance and endothelial function. Therefore, the available body of scientific evidence indicates that consumption of β-glucan soluble fiber products may mediate yet another CHD risk factor.

3. Beneficial Impact of Cereal Fiber Consumption on Reduced Risk of Cancer

A growing body of scientific evidence has linked whole-grain consumption with a reduced risk of several types of cancer. As a result a whole grain/cancer and heart disease health claim was approved by the FDA in 1999. The claim is as follows;

Diets rich in whole grain foods and other plant foods and low in total fat, saturated fat, and cholesterol may reduce the risk of heart disease and some cancers.

Jacobs et al (1998 a,b) analyzed 40 studies of 20 forms of cancer published between 1984 and 1997. Thirty-seven case control studies identified an association between consumption of whole-grain and various forms of cancer. Similarly three review articles, one ecological study and a meta analysis of 40 case control studies concluded that consumption of whole grain foods was associated with a reduced cancer risk. Whole grain consumption consistently reduced the risk of neoplasm by 30-70 % (oral cavity and pharynx, esophagus, stomach, colon, rectum, liver, bladder, larynx, breast, ovary, prostate, gallbladder, kidney and non-Hodgkin's lymphoma). In the case of colon cancer 24 studies found a positive relationship between cereal and cereal fiber consumption and reduced risk of colon cancer while seven studies did not support an association.

Weimer (2002) summarized the data as follows;

- A reduced risk for cancer with higher whole-grain intake despite the type of dietary intake methodology used.
- A strong consistency and a moderately strong magnitude of association between whole-grain intake and reduced risk for cancer.
- A moderately strong dose relationship between increased whole grain intake and reduced risk for various cancers.
- A persistent association between whole grain intake and reduced risk of cancer, even when other confounding variables (e.g. diet, exercise, smoking and alcohol uses) were controlled.

Several potential biological mechanisms have been identified which might be involved in reducing cancer risk. Whole grains are rich sources of fermentable carbohydrates (dietary fiber, resistant starch and oligosaccharides). The undigested carbohydrates are fermented by intestinal microflora in the colon. The primary fermentation end products are short chain fatty acids such as acetic, butyric and propionic acids. These short chain fatty acids have been correlated to lower serum cholesterol and reduced risk of cancer (Cummings et al, 1992). Whole grains also contain a wide range of antioxidants such as phenolic acids, tocotrienols, phytoestrogens and phytic acid, all of which have been associated with reduced risk of cancer. Phytic acid, which is sometimes referred to as an antinutrient, has a useful antioxidant function. It forms chelates with various metals which suppresses iron catalyzed redox reactions (Graf and Eaton, 1993). This mechanism is proposed to suppress the oxygen radicals produced by colonic bacteria fermentations. Phytoestrogens (ligands) are thought to alter serum hormone levels and thus reduce cancer risk (Adlercreutz, 1990; Adlercreutz et al. 1987; Goldin et al. 1982).

A few animal studies have addressed the role of barley fiber in reducing risk of cancer. McIntosh et al (1996) compared barley bran diets which varied in insoluble and soluble fiber content to a wheat bran diet in tumor-induced rats. Some of the barley brans were comparable to wheat bran in decreasing tumor incidence and tumor mass index. One of the most effective barley brans was prepared in a manner similar to oat bran and contained 13% total fiber which was 40% soluble. In an earlier study (McIntosh et al 1993), spent barley grains (same as BSG) containing mostly insoluble fiber was comparable to wheat bran. Zhang et al (1992) reported that ingestion of BSG reduced the secondary to primary bile acid ratio in hamsters and preferential adsorption of lithocholic acid by barley fiber has been demonstrated (Huang and Dural 1995). Excessive concentrations of secondary bile acids have been suggested as one cancer promoting mechanism (McIntosh 1993).

Foods that meet the whole grain health claim criteria are eligible to display the whole grains health claim. The epidemiological studies clearly demonstrate that increased consumption of whole grain products can provide positive health benefits. Whole grain barley products meet these criteria and may deliver significant health benefits to the U.S. population. Also, all low GI (total/soluble fiber enriched) barley fractions may (in addition to the reduced risk of CHD) deliver the benefit of reduced cancer risk.

4. Beneficial Impact of Whole Grains on Weight Control

The 1998 World Health Organization survey data (Mokdad et al 2003) indicated that 50% of all adult Americans are either overweight or obese. This could become a serious burden on the U.S. health care system as our population ages. Additionally, it has dramatic effects upon the "quality of life".

Whole grains are generally low in total and saturated fat and high in dietary fiber, subsequently, they are thought to have beneficial effects upon weight control. Unfortunately, no long term clinical trial has been conducted to provide direct conclusive evidence regarding the direct effects of whole grains on weight control. However, there is a growing body of scientific evidence from both epidemiological and short-term experimental studies that suggests that high GI diets that contain refined grains play a role in obesity (Ludwig et al, 1999a; Roberts and Heyman, 2000). Roberts and Heyman (2000) in a review of human clinical trials concluded that consumption of low GI-foods was directed associated with a reduction in subsequent hunger (increased satiety) which leads to lower voluntary energy intake. Two recent epidemiological studies of dietary fiber suggested that intake of whole grains but not of refined grains was inversely correlated with body weight and fat distribution (Fukagawa et al, 1990; Ludwig et al, 1999b). Additionally, an association has been observed between dietary fiber intake and prevalence of obesity in the U.S. population. In a study comparing normal-weight, moderately obese, and severely obese individuals in the U.S., normal-weight individuals consumed almost 19 g of fiber daily, while obese individuals consumed between 13 and 14g (Alfieri et al, 1995).

Additional studies are required to confirm the inverse association between intake of whole grains and weight changes. However, there is good evidence that consumption of whole grains especially those with low GI's may impact obesity. Barley's low GI, low fat and high level of soluble fiber bode well for the possibility that consumption of barley products would be of benefit in a weight control diet.

In summary, the data strongly suggests increased consumption of cereal grains, including barley products, will assist consumers in losing weight. Thus consumers, who adhere to the grain consumption recommendations of health based scientific groups and the USDA/USDHHS dietary recommendations, should receive some significant weight related health and "quality of life" benefits. Unfortunately only 34% of women and 29% of the women(all ages) who participated in the 1994-1996 USDA CSFII/Diet and Health Knowledge Survey (Wilson et al, 1997) said that it was very important to them personally to "choose a diet with plenty of breads, cereals, rice and pasta".

One final statistic, according to the Center for Disease Control and Prevention (CDC 2000) America's population of senior citizens (65 or older) is expected to increase from 35 million today to 71 million by 2030. Thus, it is extremely important that the well documented health benefits of consuming grain products be clearly communicated to the U.S. public so that the "golden years" are truly golden. This positive message will enhance "quality of life" and significantly reduce the financial burden on our national health care system.

F. No Significant Adverse Effects

As outlined in the *"Oatrim (Beta Trim^{TM})" Health Claim Petition* (Quaker Oats 2001) no studies to date have provided any evidence of significant adverse effects such as gastrointestinal disturbances, choking or vitamin-mineral mal-absorption related to the intake of β-glucan soluble fiber containing oat products. A similar conclusion can be made for barley foods containing β-glucan soluble fiber.

All of the previously discussed human clinical trials (section III.B.1) took note of potential gastrointestinal disturbances that could be associated with barley consumption. Subjects in these studies consumed from 44 to 175g of barley and reported some bloating and flatulence which would be expected in adjusting to a high fiber diet. Overall, no serious adverse effects were reported (Newman et al 1989a; Narain et al 1992; Pick et al 1998; Pins et al 2000; Behall et al 2004). In a recent study Hallfrisch and Behall (2003c) compared oat bran, barley flour and barley and oat β-glucan extracts prepared in puddings and eaten as part of a glucose tolerance test. Gastrointestinal symptoms were monitored before and after consumption of the test meals but none of the reported symptoms were related to the barley or oat products.

No toxicity has been reported in animal studies using barley β-glucan soluble fiber extracts. Delaney et al (2003b) fed Wistar rats 3 levels of extracted barley β-glucan for 28 days and concluded there were no adverse effects on general condition and behavior, growth, feed and water consumption, feed conversion efficiency, red blood cell and clotting potential parameters, clinical chemistry values and organ weights. Overall, no signs of toxicity were detected even when large amounts were consumed. In a further study, Delaney et al (2003c) used the same protocols in CD-1 mice, used frequently to evaluate inflammatory responses. Following 28 days of consumption and 14 days of recovery period, no treatment-related adverse effects were observed in hematology or clinical chemistry measurements or in organ weights and immunopathology. The researchers concluded that concentrated barley β-glucan did not cause treatment-related inflammatory or other adverse effects.

Vitamin-mineral mal-absorption associated with barley fiber has been examined in only a few human and animal studies. Wisker et al (1991) examined the calcium, magnesium and zinc balances and iron absorption in young women eating a diet which contained 15g/day of barley fiber which was 97% insoluble and low in phytic acid (0.06%). This fiber was derived from the outer layers of the grain and contained no husk. The fiber had no effect on the mineral balances or absorption of iron except when protein intake was decreased. Sandstrom et al (1987) reported that individuals absorbed significantly higher levels of zinc when consuming barley porridge and bread than when consuming oatmeal, wholewheat or triticale porridges or breads. Harrington et al (2001) reported that calcium absorption in rats was unaffected by a barley fiber but was decreased by a wheat fiber. The barley fiber was 88% insoluble and 12% soluble.

In vitro binding studies parallel the *in vivo* studies. Kennefick and Cashman (2000) reported barley bound significantly less calcium than wheat. Weber et al (1993) analyzed the calcium binding capacity of 18 fibers including barley that had 3.5% soluble and 57.1% insoluble fiber. The barley fiber ranked 4 out of 18 for level of phytic acid, but only 9 out of 18 for amount of calcium bound. The scientists reported that in this study there was no correlation between total calcium bound and phytic acid ($r=-0.12$). In a similar study (Idouraine et al 1995), barley fiber bound more copper than 16 other brans, but less magnesium than 11 and less zinc than 4 other brans. Persson et al (1991) analyzed *in vitro* binding of copper, cadmium and zinc to the soluble fiber from barley, oats and rye. All of the fibers bound more copper than zinc or cadmium and barley appeared to bind more of the minerals than the oats and rye but no statistics were reported. However, none of these soluble fibers bound as much zinc as wheat bran. And, purified barley β-glucan did not bind to any of the minerals.

Barley has mainly been consumed in the form of pearled barley or ground meal and as such has a long history of safe use. It has a defined reference amount per eating occasion of 45g dry. But as recent as 1961 barley was consumed at levels as high as 226g/day in Morocco. This would be equivalent to approximately 11g of soluble fiber and 20g of insoluble fiber. Consumption in the U.S. is and would continue to be considerably lower even with increases associated with authorization of a health claim. The increases in consumption of oat products associated with the authorization of the oat soluble fiber health claim was not sufficient to cause any concern about the levels of fiber consumption. In fact the fifth edition of the USDA/USDHHS (2000) "*Nutrition and Your Health: Dietary Guidelines for Americans*" places additional emphasis on increasing the intake of grain products.

Barley contains gluten protein similar to wheat. The wheat gluten protein can trigger an autoimmune disease called celiac disease in genetically susceptible individuals. As with wheat, products that contain barley cannot carry the "gluten free" label. Individuals that have the disease will recognize barley in the ingredient label and can choose accordingly.

In summary, the Oatrim petition documents that there were no adverse effects associated with the increases in oat consumption in response to the whole oat β-glucan soluble fiber heart health claim. Based on the strong similarity between oat and barley products and the fact there is not any naturally occurring components in barley that raise a flag regarding a health or safety issue, we conclude that increased consumption of barley products containing β-glucan soluble fiber will have no adverse effects upon the U.S. population.

IV. NATURE OF THE SUBSTANCE AND FOODS ELIGIBLE TO BEAR THE CLAIM

The National Barley Foods Council requests that the FDA approve barley β-glucan soluble fiber and barley products containing β-glucan soluble fiber, including dehulled or hulless barley and pearl, flakes, grits, meal, flour, β-glucan enriched meal or flour fractions, and bran for health claims on the basis of the criteria outlined in 21 CFR 101.14.

A. Products Eligible to Bear the Claim

The petitioners request that the FDA amend CFR 101.81 to include barley products, including dehulled or hulless barley and pearl, flakes, grits, meal, flour, β-glucan enriched meal or flour fractions, and bran derived from either dehulled or hulless barley as eligible sources of β-glucan with barley β-glucan contents of a minimum of 4% β-glucan (dry weight).

The β-glucan soluble fiber and total fiber content of barley grain was presented in Table 8. Many of the barley products derived from the grain will contain as much or more than their source material. Table 11 lists various barley products that have been used in clinical trials and process/product development studies and the range of β-glucan content reported in these published studies. While most of the products contain at least 4% β-glucan, those that do not would not be eligible for the claim. Manufacturer's specifications have been included in Appendix 2 to illustrate the range of barley products commercially available. Because barley is recognized as an excellent source of both total and soluble fiber, most manufacturers already specify a level of total dietary fiber at 10% or greater.

The petitioners initiated a study of the β-glucan content of selected manufactured and commercially available barley and oat products in 2001. The data is provided in an unpublished (Fastnaught and Hadley, 2002) report included in Appendix 3. Pearl barley manufactured in Idaho and Minnesota in 2001 and 2002 from dehulled barley had a β-glucan soluble fiber content ranging from 4.77 to 5.04%, respectively. Steam rolled flakes and flour, both made from the Minnesota pearl barley, had a β-glucan soluble fiber content identical to their source. A sieved flour fraction made from the flour had a higher β-glucan soluble fiber content (8.63%). Similar results were obtained in 2002. Two samples of pearl barley purchased in grocery stores in North Dakota and Florida both had a β-glucan soluble fiber content of 5.65%. In contrast, two brands of quick oats purchased in a North Dakota grocery had 2.92 and 4.19% β-glucan soluble fiber.

B. Qualifying Levels of β-glucan Soluble Fiber and Fiber Analysis

Section § 101.81 of the health claim final rule established 3 g of oat β-glucan as the effective daily intake (FDA 1997a). This level has been previously established as the minimum daily intake to significantly lower cholesterol.

Table 11. Typical β-glucan soluble fiber levels in barley foods reported in published articles.

	No.	β-glucan % (dwb)[a] Range	Mean	References
Whole berries				Bhatty 1997; Dudgeon et al 1997; Klamczynski et al 1998; Kiryluk et al 2000; Marconi et al 2000;
Covered-dehulled	6	3.3 – 4.6	4.2	
Hulless	8	4.1 – 7.3	5.8	
Pearl				Bhatty 1997; Yeung and Vasanthan 2001; Klamczynski et al 1998; Marconi et al 2000; Dudgeon et al 1997
Covered	4	3.4 – 4.7	4.2	
Hulless	6	4.1 – 6.8	5.7	
Flakes	3	2.8 – 5.7	4.5	Sundberg et al 1994
Cracked/Grits	1	7.1	7.1	Pick et al 1998
Meal	6	4.1 – 6.9	5.6	Berglund et al 1992; Berglund et al, 1994; Dudgeon et al 1997
Flour concentrate –ground and sieved	2	9.0 – 18.9	14.0	Hudson et al 1992; Dudgeon et al 1997
Flour – impact milled/air-classified				
Covered	15	4.0 – 12.0	6.7	Andersson et al 2000
Hulless	20	3.0 – 23.0	8.0	
Flour – roller-milled 45 to 70% flour extraction				Newman et al 1990; Danielson et al 1996; Bhatty 1997; Kiryluk et al 2000; Klamczynski and Czuchajowski 1999
Covered	3	2.7 – 4.2	3.3	
Hulless	10	3.0 – 6.0	3.9	
Bran – roller-milled 45 to 70% flour extraction				Bhatty 1993a; Bhatty 1995; Danielson et al 1996; Bhatty 1997; Kiryluk et al 2000; Klamczynski and Czuchajowski 1999
Covered	4	5.9 – 8.7	7.2	
Hulless	10	5.4 – 13.4	8.1	
Bran – pearled 20-32%				Bhatty 1997; Dudgeon et al 1997; Marconi et al 2000; Yeung and Vasanthan 2001
Covered	2	3.6 – 4.5	4.1	
Hulless	5	2.8 – 6.6	4.7	

[a]dwb = dry weight basis

The oat β-glucan soluble fiber rule (FDA 1997a) indicated that the rolled oats, oat bran and whole oat flour foods eligible to bear the claim were those that contained at least 0.75 g of soluble fiber per reference amount typically consumed (RACC). This amount was determined by dividing the 3g of soluble fiber per day by four eating occasions per day. Dehulled and hulless barley and products derived from them are excellent sources of β-glucan soluble fiber. The chemical and physiological bioequivalence of oat and barley β-glucan soluble fiber has been established in this petition. Individuals that consumed barley foods supplying 6g of barley β-glucan soluble fiber in the Behall et al (2004) study had a minimum of 8.8% and up to 16.6% lower total cholesterol. This is equivalent or greater than the reduction predicted for 6g of oat β-glucan soluble fiber. Therefore we propose that foods containing β-glucan soluble fiber from dehulled and hulless barley and products derived from them meet the same 3 g daily intake of β-glucan soluble fiber and 0.75 g of soluble fiber per RACC requirement of eligible food.

Extending the claim to include barley β-glucan soluble fiber dramatically increases the opportunities to incorporate physiologically effective amounts of β-glucan soluble fiber into food products. Barley's high β-glucan soluble fiber content and lower fat content offer unique product development opportunities. In addition to its' use in breakfast cereals and snack items, barley (in contrast to the most common oat food applications) can be readily incorporated into dishes commonly served at the other eating occasions. For example barley can be used in stews and pilafs or incorporated into pasta. Thus, many additional foods will be available to the health minded consumer which will make it much easier to adapt a healthy life style. This will help consumers continue the trend toward consumption of more cereal products which will provide a predictable reduction in the risk of CHD.

β-glucan analysis to confirm content of both ingredients and final products is desirable. AOAC Method No. 992.28, as specified for β-glucan in oat products in § 101.81, is the preferred method for analyzing barley β-glucan (AOAC 2000). Barley and oat β-glucans are essentially equivalent, thus they do not require a separate analytical method.

C. Representative Foods That May Bear The Claim

Section § 101.81(c)(2)(iii) provides that the eligible foods can include more than one of the eligible oat sources of β-glucan soluble fiber and that the oat foods must contain a minimum of 0.75 g of β –glucan per reference amount of customarily consumed (RACC) of the eligible food. The National Barley Foods Council proposes that dehulled and hulless barley and products derived from dehulled and hulless barley be approved as an eligible source of β-glucan soluble fiber as outlined in Section § 101.81 "*Health claims: Soluble fiber from certain foods and the risk of coronary heart disease (CHD).* Eligible foods should be allowed to contain one or a combination of qualified barley sources provided that the individual sources each contain a minimum of 4% β-glucan and that total amount of β-glucan from eligible barley sources is greater than 0.75 g per RACC. In addition, the National Barley Foods Council recommends that food products eligible for the proposed barley β-glucan soluble fiber health claim also be low in saturated fat, cholesterol, and total fat and, in general, conform to the other health claim general principles (e.g. disqualifier levels).

Table 12 lists four examples of foods and β-glucan soluble fiber contents/RACC of selected barley or barley containing products that meet the criteria proposed for a barley β-glucan soluble fiber heart health claim. Additional examples and recipes provided in Appendix 4 illustrate that β-glucan soluble fiber content/RACC will vary depending upon the β-glucan content of the source grain.

Table 12. Typical Barley Foods and β-glucan Content/RACC

Food Category	Description of Foods	Serving Size	Minimum. β-glucan g /serving
Hot Cereal	Barley Flakes +/- fruit & nuts	40 g flakes	1.4
Pasta	Spaghetti or other pasta forms	56 g	0.8
Whole grain side-dishes	Barley pilaf	48 g	1.7
Snacks	Tortilla chips - 50% barley flour	28 g	1.1

D. Projected Impact Upon Food Consumption

In order, to estimate the impact of a heart health claim for barley and derived products and CHD on barley consumption and the consumers dietary choices, it is useful to look at the effects of previous health claims and nutritional/dietary educational programs on consumer choices.

The USDA/USDHHS's *Dietary Guidelines for Americans* were first issued in 1980. The 1980 guideline statement was " Eat foods with adequate starch and fiber". The accompanying text provided rational for increasing consumption of foods high in fiber and starch. Whole grain breads and cereals, enriched grains, fruits, vegetables and dry beans and peas were identified as healthy foods that should be consumed with increased frequency while reducing fat and sugar intake. As our nutritional knowledge base expanded the USDA/USDHHS placed increased emphasis on the consumption of cereal foods especially foods containing whole grain cereals. The most recent USDA/USDHHS (2000) nutrition guidelines reads "Choose a variety of grains daily, especially whole grains". Although the guideline did not specify a specific number of whole grain servings it did place increased emphasis on the health benefits of consuming whole grain products. The committee cited two factors that provided the basis for the latest guidelines. First, there is a very low intake of whole grains in the U.S. Secondly, there is a developing body of scientific evidence that specifically demonstrates the health benefits associated with consumption of whole grain products.

Examination of consumption data shows the USDA/USDHHS dietary guidelines have had a significant impact upon Americans dietary choices. Table 13 shows the per capita levels of food energy and the amount of grain consumed annually for the years 1909, 1972 and 1997. The per capita consumption of grain products hit an all time low of 133 lbs per capita in 1972. Consumption rose to 196 lbs per capita in 1997, far below the 1909 level but 47% higher than the 1972 low. In 1909 grains were the major source of calories (39%), carbohydrates (57%) and protein (37%). In the 1997 assessment, the majority of protein came from meat, poultry and fish (38%) while fats and sugars provided the majority of calories (38%). Concurrently a rise in total caloric intake (300 kcal) was observed from 1909 to 1997 (and 500 kcal more than 1972) due to the large increase in fat and sugar intake. The growth in fat and sugar consumption has negative health implications as noted by the increases in obesity in the U.S. population. The small increase in fat consumption between 1972 and 1997 suggests that nutritional education has had a significant positive impact upon some consumer dietary choices but consumption of cereal products is still well below the recommended levels and may have reached a plateau.

Table 13. Per Capita Levels of Food Energy and Selected Nutrients in the U.S. Food Supply from 1909 to 1997[a]

	Total Food Supply			Contributed by Grains					
	Per Capita per Day			Per Capita per Day			% of Total		
Item	**1909**	**1972**	**1997**	**1909**	**1972**	**1997**	**1909**	**1972**	**1997**
Food Energy, kcal	3,500	3,300	3,800	1,365	640	988	39	19	26
Carbohydrate, g	500	389	509	284	133	206	57	34	40
Protein, g	101	97	112	38	18	27	37	18	24
Fat[b], g	122	152	156	5.2	2.1	4.7	4.3	1.4	3.0
Total annual per capita grain food, lb				300	133	196			

[a] Adapted from Kantor etal 2002
[b] Includes fat naturally present in grains. Excludes fat added to cookies, corn chips and similar products.

Current sales volume data provides some insight on consumer eating trends. Table 14 shows the annual supermarket volume sales of selected grain products and whole grains for the years 1995 and 1999. The data shows significant declines for most cereal categories except hot cereals, ready-to-eat cereals containing oats, whole grain breads and tortillas. Oatmeal sales and oat based ready-to eat cereal consumption increased 8.8% and 6.1% respectively. This time period covers the time immediately before and after the authorization of the oat soluble fiber health claim and provides an excellent measure of the health claim's impact on consumer behavior. During the same time period consumption of rice products declined 7.9%, breads and rolls declined 2.5%, pasta consumption declined 11.2% and total ready-to-eat cereal consumption declined 6.8%. Thus, it appears that in spite of the increased emphasis on cereal consumption

Table 14. Whole-Grain Share of Annual Supermarket Volume Sales of Selected Grain Products[a]

Product Group	Unit	1995	1999
Rice, total	lb	780,074,073	718,459,604
Non-whole grain	lb	740.615.961	684,664,278
Whole grain[b]	lb	39.458.112	33,795,326
Whole grain share of total	%	5.1	4.7
Flour, total	lb	320.571,061	325,405.896
Non-whole grain	lb	287,576,367	298,763,794
Whole grain[b]	lb	32.994,694	26,642,104
Whole grain share of total	%	10.3	8.2
Cereal grains, total	lb	7,272,091	6,302,425
Non-whole grain[d]	lb	398,599	268.129
Barley	lb	5,599,195	5,007,020
Other whole grain [e]	lb	1,274,297	1 .027,276
Whole grain share of total	%	94.5	95.7
Ready-to-cook breakfast cereals, total	lb	338,131,054	345,466,226
Non-whole grain	lb	68,107,657	53,161,800
Oats	lb	267,172,150	290,611,466
Other whole grain[f]	lb	2,851,247	1,692,960
Whole share of total	%	79.9	84.6
Ready-to-eat breakfast cereals, total	lb	2,706,046,847	2,521,244,876
Non-whole grain	lb	1,714,252,708	1,600,560,492
Oats	lb	440,311,865	467.277,464
Other whole grains[g]	lb	115,263,540	108,981,953
Whole grain share of total	lb	20.5	22.8
Breads and rolls, total	lb	5,836,440,080	5,693,164,554
Non-whole grain	lb	5,670,618,542	5,508,519,810
Whole grain [h]	lb	165,821,538	184,644,744
Whole grain share of total	%	2.8	3.2
Pasta, total	lb	631,528,920	560,585,021
Non-whole grain	lb	630,417,940	577,927,893
Whole grain [i]	lb	1,110,980	2,657,128
Whole grain share of total	%	0.2	0.5
Tortillas, total		471,648,508	542,382,238
Non-whole grain	lb	468,926,091	539,715,027
Whole grain [j]	lb	2,722,417	2,667,211
Whole grain share of total	%	0.6	0.5

[a]Taken from Kantor et al 2002

[b] Brown rice and wild rice

[c]Spelt, graham, millet.. amaranth. teff. oats, barley, brown rice, quinoa. cracked wheat, buckwheat, kamut, triticale, rye, wheat bran, bulgur wheat and whole wheat

[d] regular couscous

[e]wheat bran. quinoa, whole wheat couscous, amaranth, millet, spelt, cracked wheat, tabouli. buckwheat/kasha bulgur wheat & oats

[f]Cracked wheat, brown rice. barley. rolled oats. triticale. rolled wheat, millet, oatmeal, bulgur. whole wheat, kamut, wheatberry, wheat bran. buckwheat and rye.

[g] brown rice, wheat spelt. rice bran. amaranth, kamut. barley. millet, corn bran, buckwheat, rye, cracked wheat, bulgur and wheat bran

[h] Whole wheat and whole grain

[i] Whole wheat. buckwheat, whole grain and bran.

[j] Whole wheat flour tortillas.

that we are seeing a recent decline in overall cereal consumption with the exception of those products that are eligible for health claims. Furthermore as the supermarket sales volume data shows, the increase in oat consumption, although significant, was very modest.

Table 15 provides an assessment of the percentage of the population that meets the grain serving recommendations for the time periods 1989-1991 and 1994-1996 (Kantor et al 2002). The data presented in this table was collected as part of the "Continuing Survey of Food Intake by Individuals" (CSFII). This USDA survey is collected by trained interviewers in respondent's homes on two consecutive days using a 24 hr multiple-pass recall method. The data shows an increase in total grain consumption over that time period. The number of individuals who reported in 6 or more servings of total grains rose from about 44 % to about 52%. However, about 90% reported eating less than 3 servings of whole grains per day. Based on the decline in grain product supermarket volume sales data (Table 14), the number of people consuming 6 or more servings of total grain products in 1999 should decline to near the 1989-1991 number.

Issuance of a health claim for barley and products derived from barley and CHD has the potential to significantly increase the consumption of barley and barley β-glucan soluble fiber. In an attempt to further evaluate the impact of a barley β-glucan soluble fiber health claim on consumption, the report from the USDA's CSFII was evaluated in conjunction with the supermarket sales volume data for barley and oat products from the years 1995 and 1999 (Table 16). Both barley and oat consumption values are too small to merit individual categories in the published CSFII report. Thus, their consumption levels were reported in the total cereal grains summary column which included grits other cooked cereals, baby cereals as well as rice, pasta

Table 15. Percentage of the Population Meeting Grain Serving Recommendations[a,b]

Recommendation/Population Subgroup	Percentage Meeting Recommendations 1989-1991	1994-1996
≥ 6 servings of total grains		
All persons <2 years	42	50
All persons aged 2-19 years	43	54
All persons aged 20-59 years	44	52
All persons ≥ 60 years	35	39
≥ 3 servings of whole grains		
All persons <2 years	9	10
All persons aged 2-19 years	7	9
All persons aged 20-59 years	10	10
All persons ≥ 60 years	9	10
1-3 servings of whole grains		
All persons <2 years	25	24
All persons aged 2-19 years	27	24
All persons aged 20-59 years	22	22
All persons ≥ 60 years	32	27
<1 serving of whole grain		
All persons <2 years	66	66
All persons aged 2-19 years	66	66
All persons aged 20-59 years	67	68
All persons ≥ 60 years	59	63

[a]Taken from Kantor et al 2002
[b]Sample servings for the grain group include one slice of bread, 1 cup of ready-to-eat cereal, or 1//2 cup of cooked cereal, rice or pasta.

and ready-to-eat cereal. However, pasta and rice consumption was significant enough to merit individual categories and thus reasonable estimates can be made for annual per capita consumption rates. According to the CSFII data the average person consumes 23g of rice and 18g of pasta per day. This equates to an annual consumption of 18.5 and 14.5 lbs of rice and pasta respectively, or one serving of rice every 2.1 days and one serving of pasta every 3.1 days. The supermarket volume data provides some additional insight that can be used to measure relative impact, % sales increase/decrease and relative volume between food categories. However, it has some limitations, for example it does not cover all retail outlets. Secondly, according to the CSFII data 26.8% of the average individuals food energy intake is consumed

Table 16. Annual Supermarket Volume Sales of Selected Barley and Oat Products[a]

Product	Volume Sales (Lb) 1995	Volume Sales (Lb) 1999	% Change 1995-1999
Cereal Flours			
Barley	62,309	114,633	84.0
Oat	15,858	24,924	57.2
Ready to Cook Breakfast Cereals			
Barley	25,609	42,643	66.5
Rolled oats	1,442,673	2,319,304	60.8
Oatmeal	118,291,791	132,721,347	12.2
Other oats[b]	145,174,331	154,334,083	6.3
Oat bran	4,706,028	3,556,036	-24.4
Ready to Eat Breakfast Cereals			
Oat bran	12,404,444	29,034,647	134.1
Barley	86,497	117,353	35.7
Other oats[b]	427,907,421	438,242,817	2.4
Cereal Grains			
Barley	5,599,195	5,007,020	-10.6
Oats	3,243	-0-	NM

[a] Modified from Kantor et al, 2002
[b] All ready to cook or ready to eat cereals made with oats except oat bran
NM = Not meaningful

outside of the home and supermarket volume sales would not reflect these sales. Thus, while it doesn't provide a good number for determining annual per capita consumption, it offers a great method for assessing the impact of things like health claims on consumers purchasing habits. The Quaker Oats Company stated in it's petition to the FDA that the total consumption of oats was 8.5lb per person per year in 1992 (Quaker Oats 1995). Using the supermarket sales volume as a guide, the total volume increase in all oat product sales between 1995 and 1999 was 6.5% which would equate to an annual per capita consumption of ~9.1lbs based on the 1992 estimate.

Using the same data and relative relationships, the annual consumption of food barley per capita is estimated to be about 0.1lb.

Barley consumption has not always been this low in the U.S. and is much higher in other countries. The USDA/Economic Research Service (USDA/ERS 2002) estimated that in 1947 per capita barley consumption as food was 6.7 lb. In Korea during the 1970's (MAF 2000), per capita barley consumption was about 35 kg (77 lb). By 1985, this had decreased to 4.6 kg (10.1 lbs) as the Korean people became more affluent and ate more rice and wheat. But even today, per capita consumption of barley in Korea is 1.6 kg (3.5 lb).

Based on the sales and consumption data the authorization of the oat heart health claim had a small but significant impact on oat consumption. The oat sales increase was not large enough to raise any concerns about a negative impact on individual consumers. Similarly, authorization of a heart health claim for barley products can be anticipated to have a positive impact on barley consumption. Since annual barley consumption is currently at a relatively low level, a two or three fold increase in barley utilization could occur as a result of a heart health claim. Most likely, consumers adding barley to their diets would substitute it for another cereal grain, such as rice or wheat (pasta), or potatoes. Substitution of a heart healthy grain product for (in most instances) a refined grain product or potatoes would not have a detrimental effect on overall nutrient intake. Also, barley does not have any anti-nutritional components that would raise any health concerns even if consumed at levels equaling oat, rice or wheat intake levels. Thus, an increase in barley product consumption can be expected to represent only one in a series of steps needed to increase the consumption of grain and whole grain products to the level required to